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Petrarca et al.

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(45) **Date of Patent: Aug. 26, 2014**

(54) **RETICLE CARRIER**

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(73) Assignee: **International Business Machines Corporation**, Armonk, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/735,470**

(22) Filed: **Jan. 7, 2013**

(65) **Prior Publication Data**

US 2013/0130162 A1 May 23, 2013

Related U.S. Application Data

(62) Division of application No. 13/278,571, filed on Oct. 21, 2011, now Pat. No. 8,439,728, and a division of application No. 11/749,384, filed on May 16, 2007, now Pat. No. 8,110,321.

(51) **Int. Cl.**
G03F 1/00 (2012.01)

(52) **U.S. Cl.**
USPC **430/5**

(58) **Field of Classification Search**
USPC 430/5, 322, 323, 324
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,565,286	A	10/1996	Lin	
5,932,377	A	8/1999	Ferguson et al.	
6,051,344	A	4/2000	Langston et al.	
6,607,862	B2 *	8/2003	Yan et al.	430/5
6,660,653	B1	12/2003	Tzu et al.	
6,821,192	B1	11/2004	Donohue	
2003/0036340	A1	2/2003	Moriya et al.	
2004/0091792	A1 *	5/2004	Kang et al.	430/5

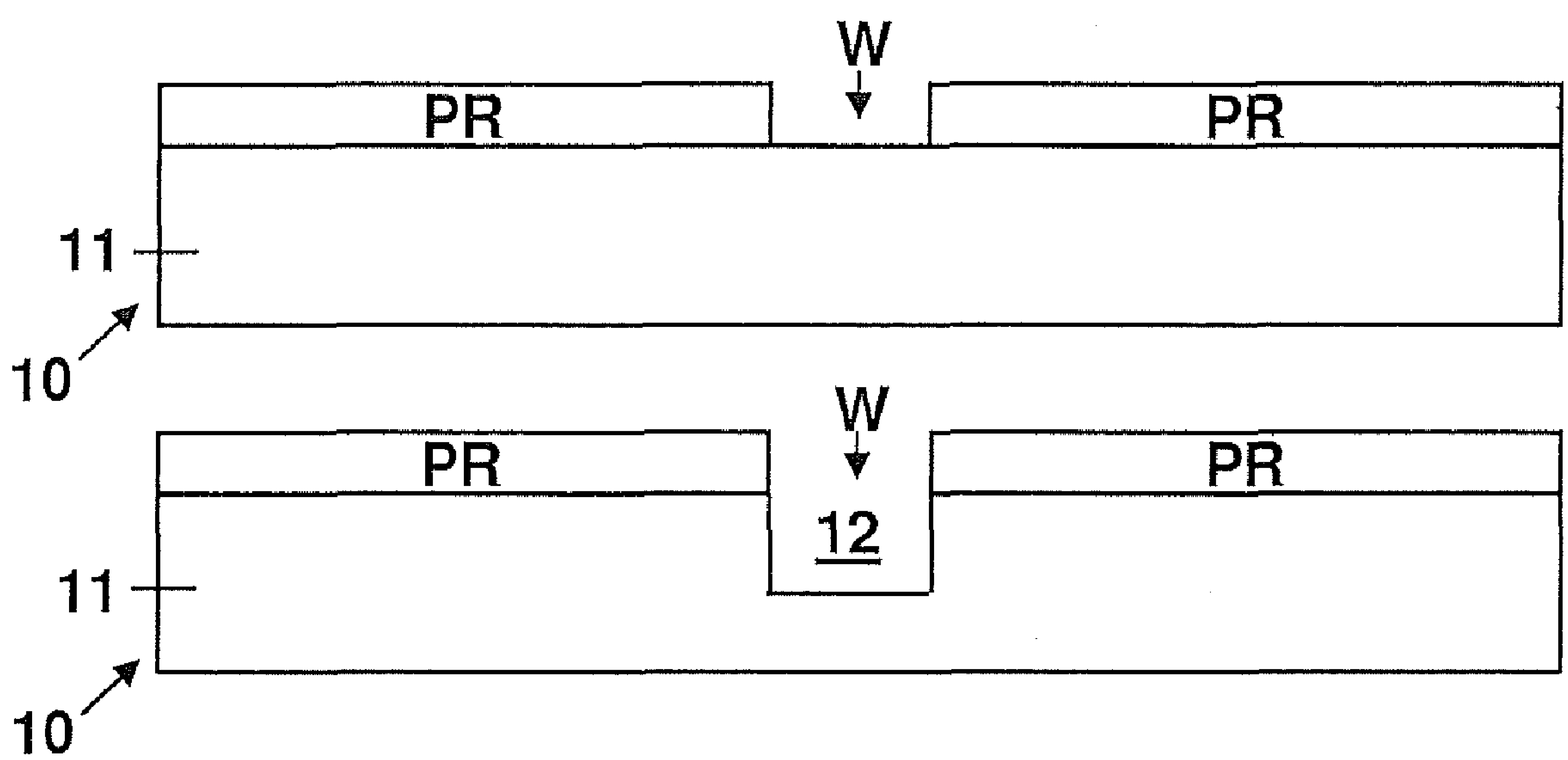
* cited by examiner

Primary Examiner — Stephen Rosasco
(74) *Attorney, Agent, or Firm* — Louis J. Percello; Ryan, Mason & Lewis, LLP

(57) **ABSTRACT**

A reticle carrier for a polishing tool capable of accommodating a reticle includes a base plate with an obverse and reverse surfaces, a retaining ring secured to the obverse surface of the base plate forming a recess defined by the obverse surface of the rigid base plate and internal edges of the retaining ring. A reticle pad supports a reticle in the recess. The base plate and the reticle pad having an array of matching, aligned passageway holes therethrough for exhaustion of air from space between the base plate and a the reticle and for supply of air to that space so a vacuum can retain a the reticle in place on the reticle carrier under vacuum conditions and application of air under pressure can eject a reticle from the reticle carrier.

7 Claims, 18 Drawing Sheets



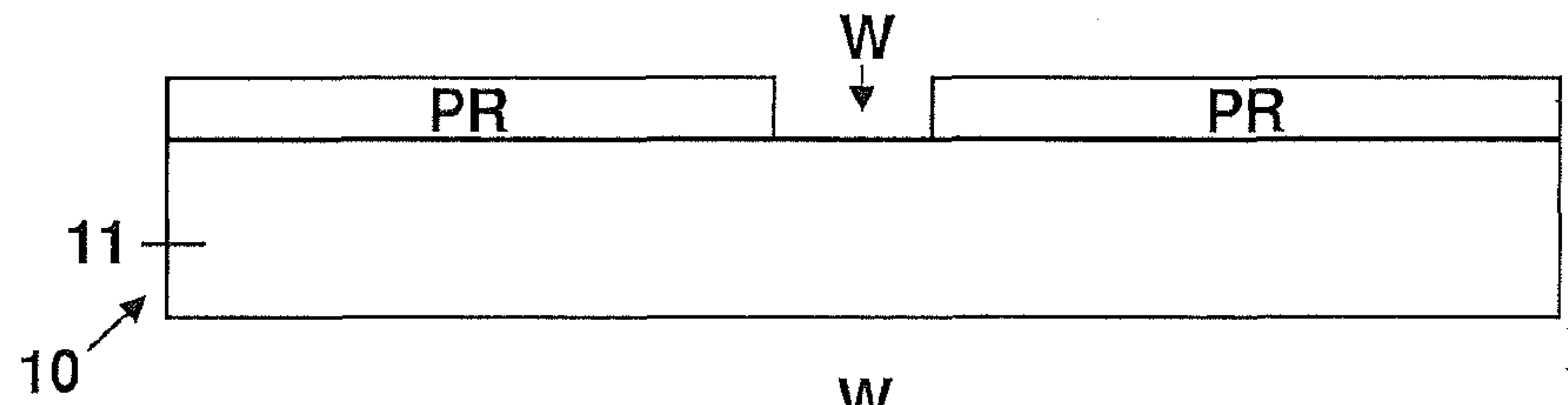


FIG. 1A

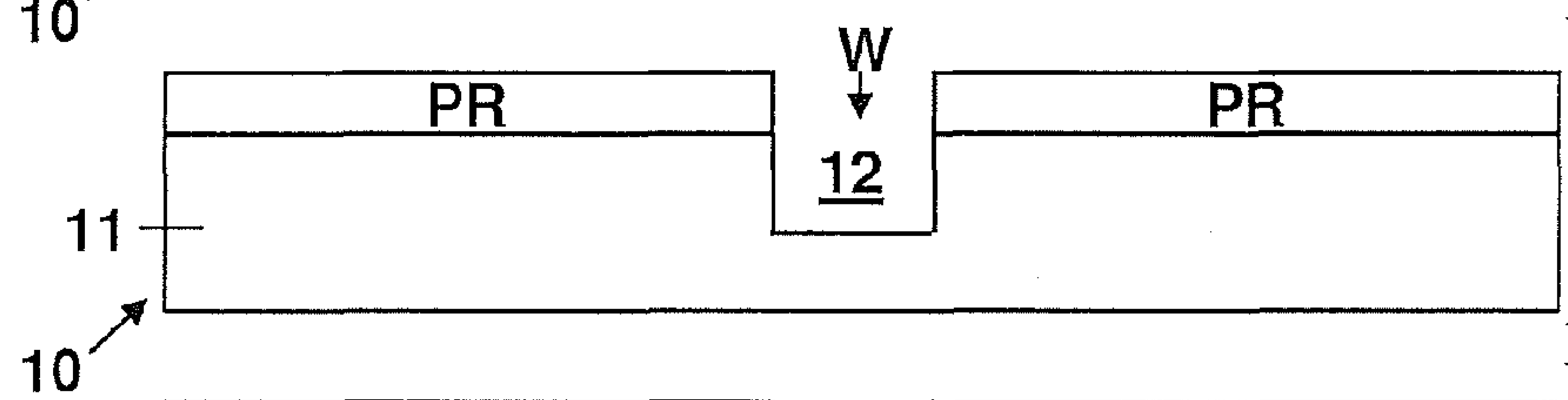


FIG. 1B

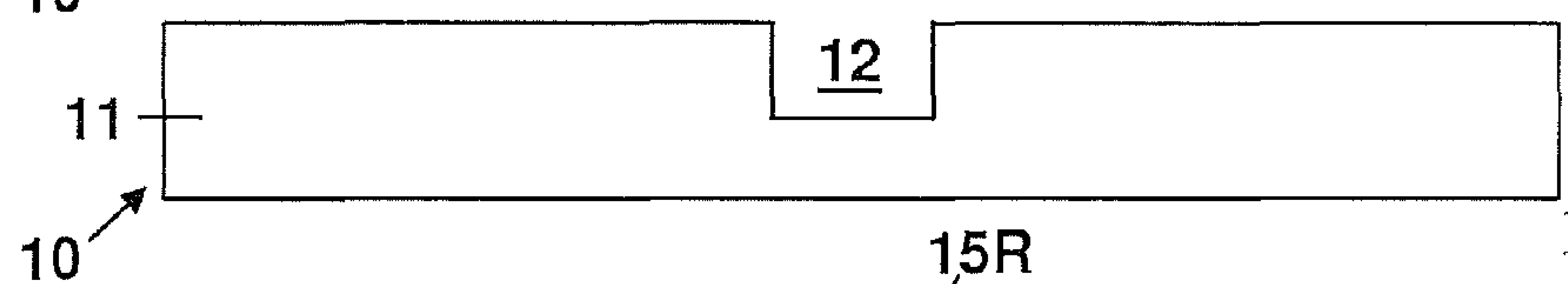


FIG. 1C

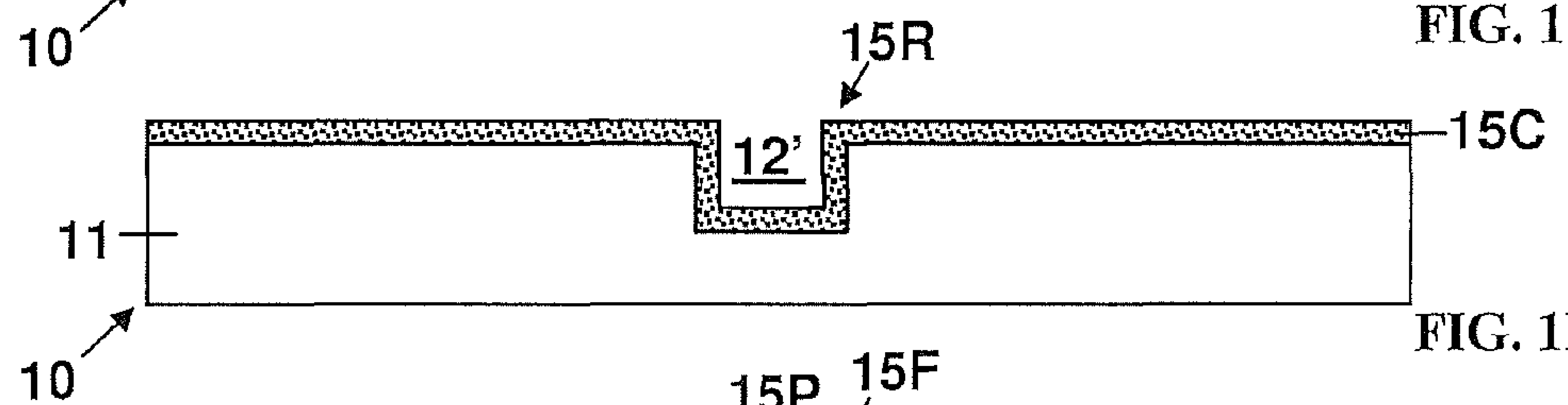


FIG. 1D

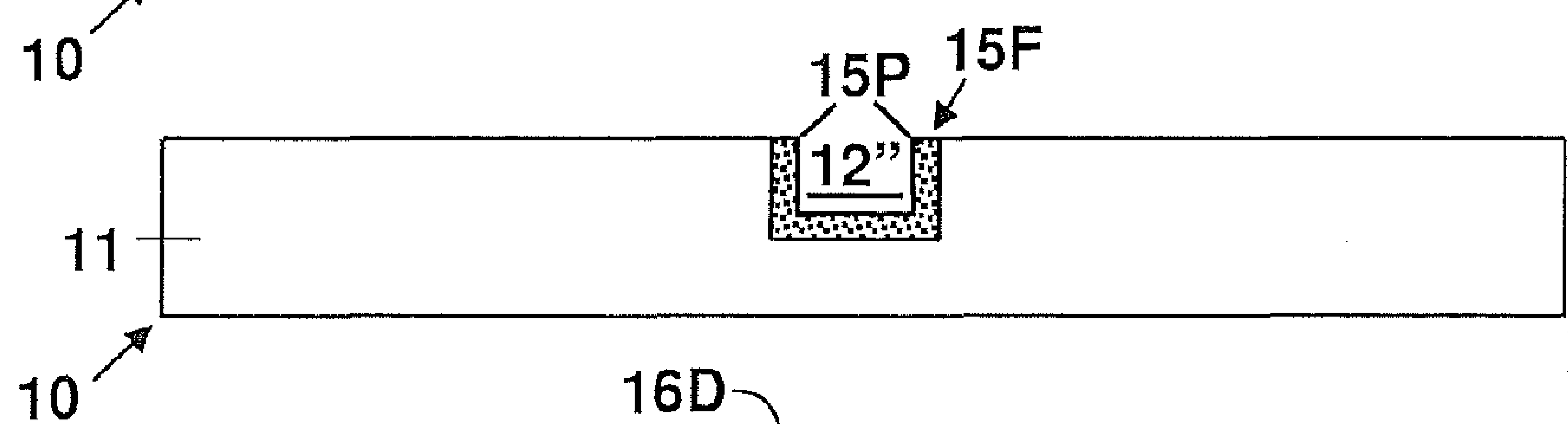


FIG. 1E

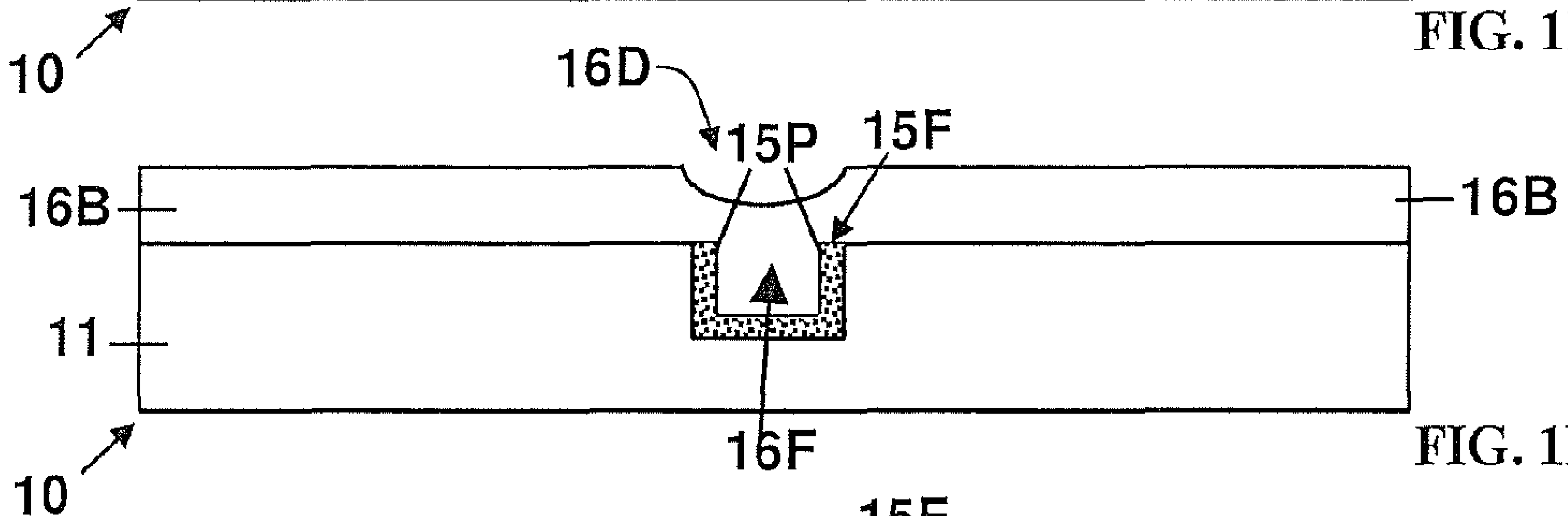


FIG. 1F

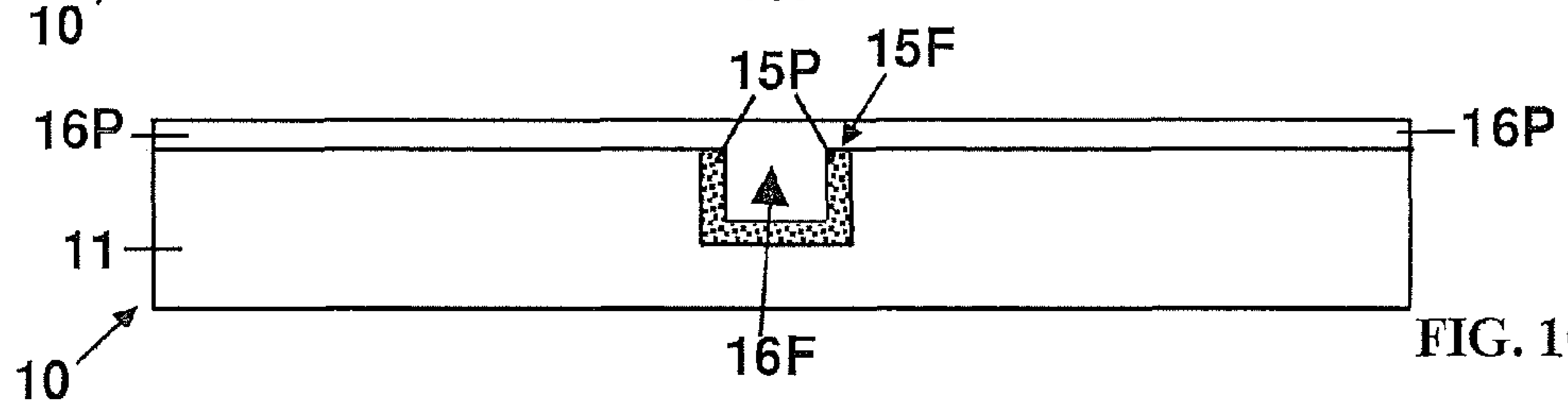
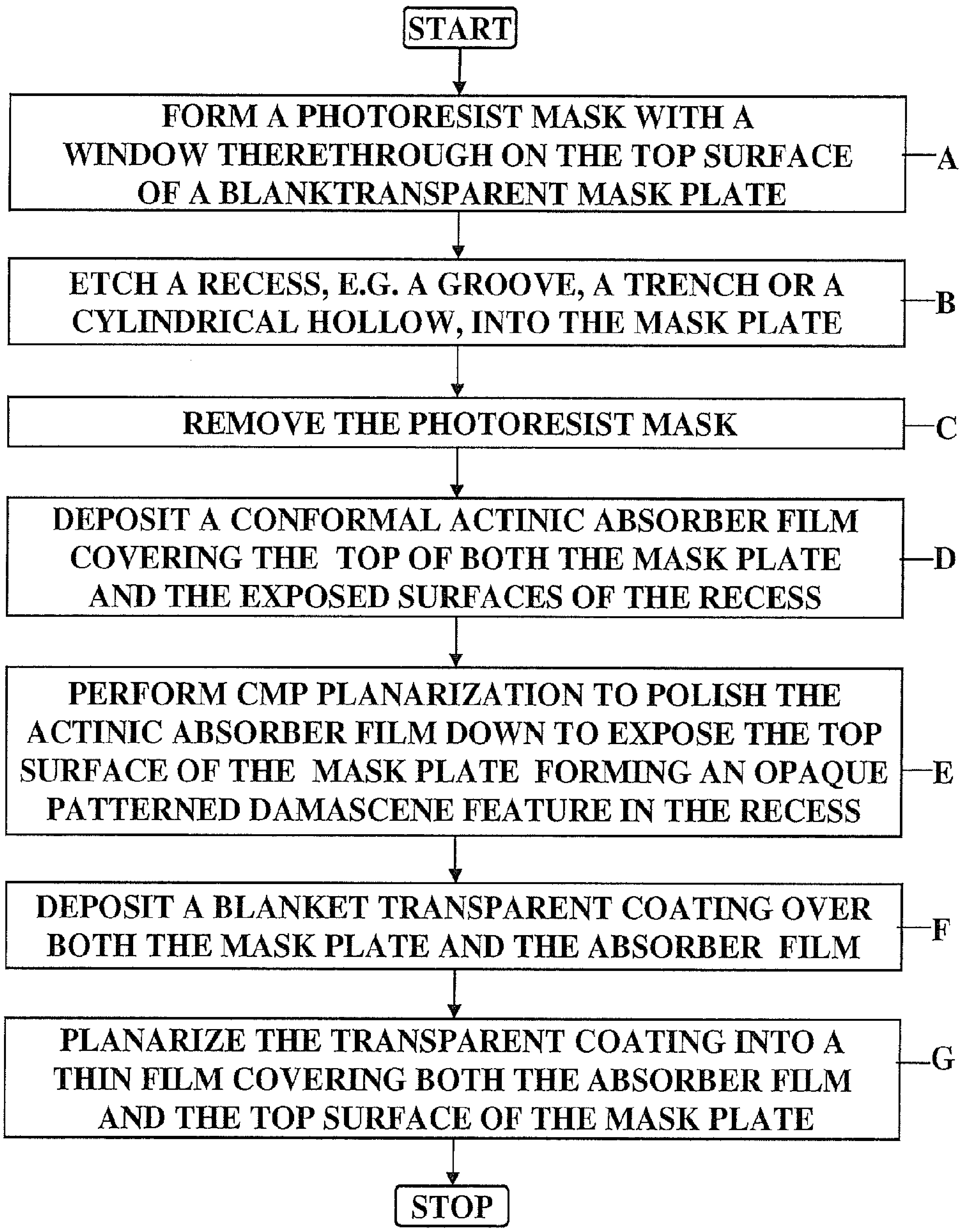


FIG. 1G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FORM A PHOTORESIST MASK WITH A WINDOW THERETHROUGH ON THE TOP SURFACE OF A BLANKTRANSPARENT MASK PLATE
A
ETCH A RECESS, E.G. A GROOVE, A TRENCH OR A CYLINDRICAL HOLLOW, INTO THE MASK PLATE
B
REMOVE THE PHOTORESIST MASK
C
DEPOSIT A CONFORMAL ACTINIC ABSORBER FILM COVERING THE TOP OF BOTH THE MASK PLATE AND THE EXPOSED SURFACES OF THE RECESS
D
PERFORM CMP PLANARIZATION TO POLISH THE ACTINIC ABSORBER FILM DOWN TO EXPOSE THE TOP SURFACE OF THE MASK PLATE FORMING AN OPAQUE PATTERNED DAMASCENE FEATURE IN THE RECESS
E
DEPOSIT A BLANKET TRANSPARENT COATING OVER BOTH THE MASK PLATE AND THE ABSORBER FILM
F
PLANARIZE THE TRANSPARENT COATING INTO A THIN FILM COVERING BOTH THE ABSORBER FILM AND THE TOP SURFACE OF THE MASK PLATE
G
STOP

FIG. 2A

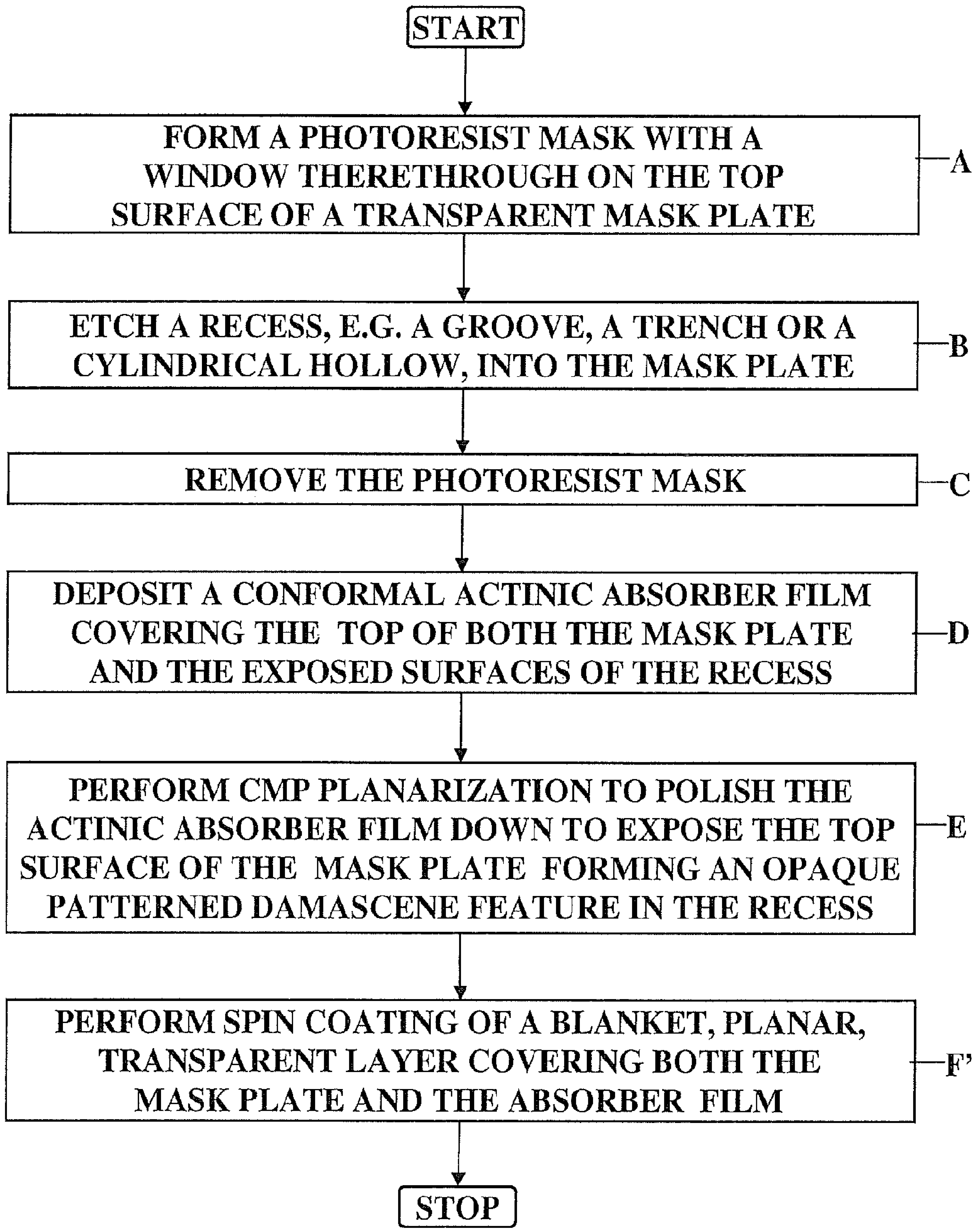

START
FORM A PHOTORESIST MASK WITH A WINDOW THERETHROUGH ON THE TOP SURFACE OF A TRANSPARENT MASK PLATE
A
ETCH A RECESS, E.G. A GROOVE, A TRENCH OR A CYLINDRICAL HOLLOW, INTO THE MASK PLATE
B
REMOVE THE PHOTORESIST MASK
C
DEPOSIT A CONFORMAL ACTINIC ABSORBER FILM COVERING THE TOP OF BOTH THE MASK PLATE AND THE EXPOSED SURFACES OF THE RECESS
D
PERFORM CMP PLANARIZATION TO POLISH THE ACTINIC ABSORBER FILM DOWN TO EXPOSE THE TOP SURFACE OF THE MASK PLATE FORMING AN OPAQUE PATTERNED DAMASCENE FEATURE IN THE RECESS
E
PERFORM SPIN COATING OF A BLANKET, PLANAR, TRANSPARENT LAYER COVERING BOTH THE MASK PLATE AND THE ABSORBER FILM
F'
STOP

FIG. 2B

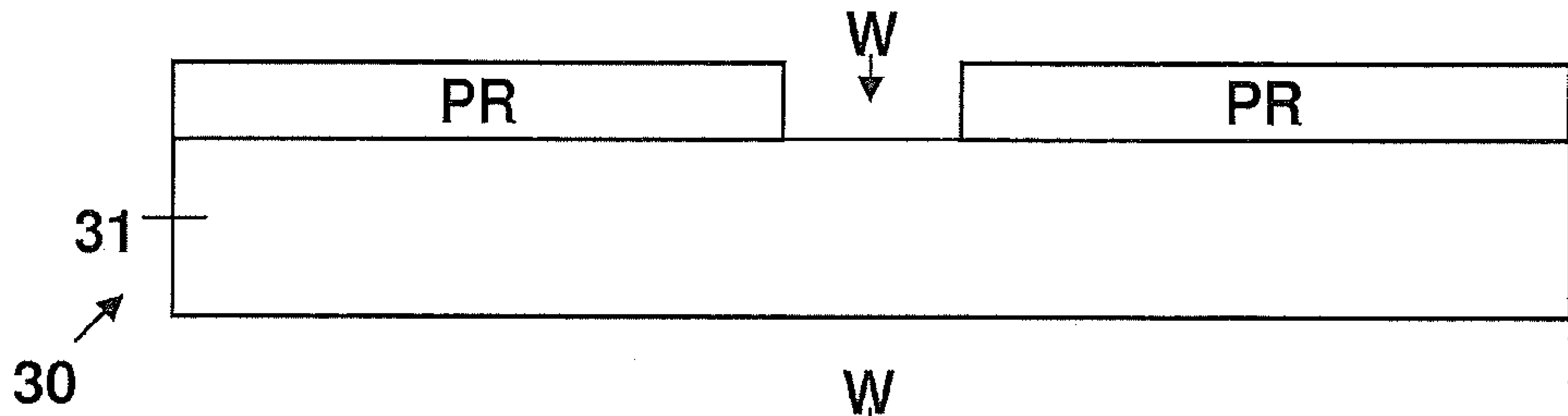


FIG. 3A

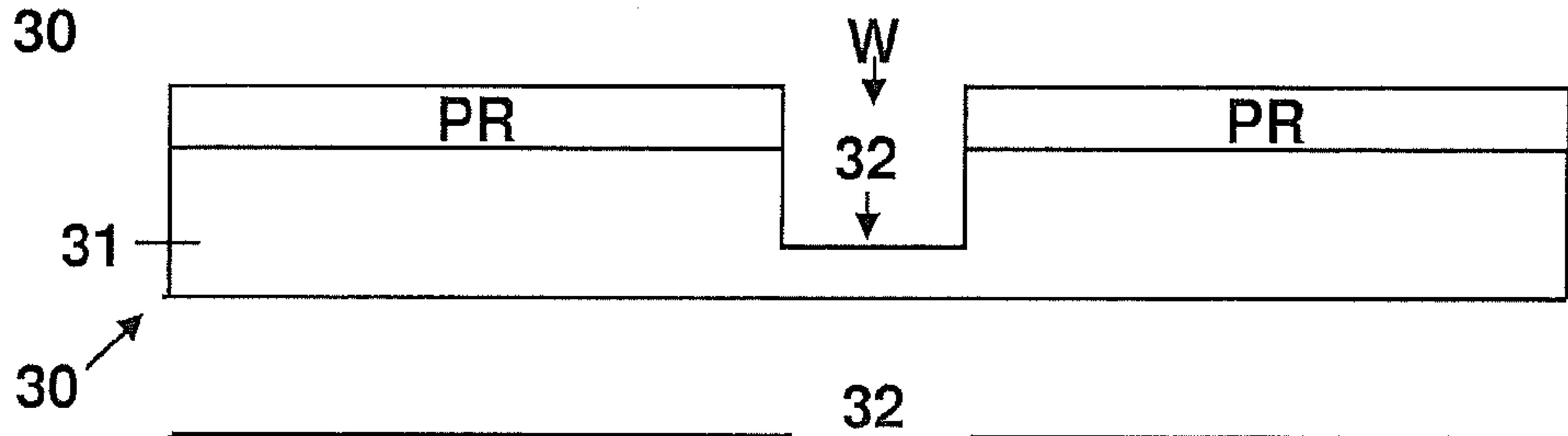


FIG. 3B

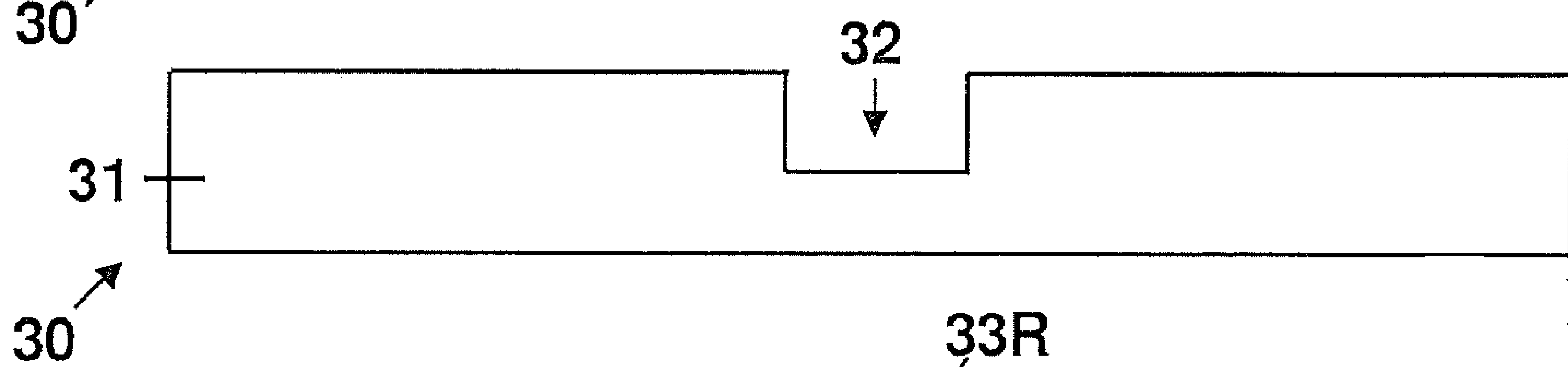


FIG. 3C

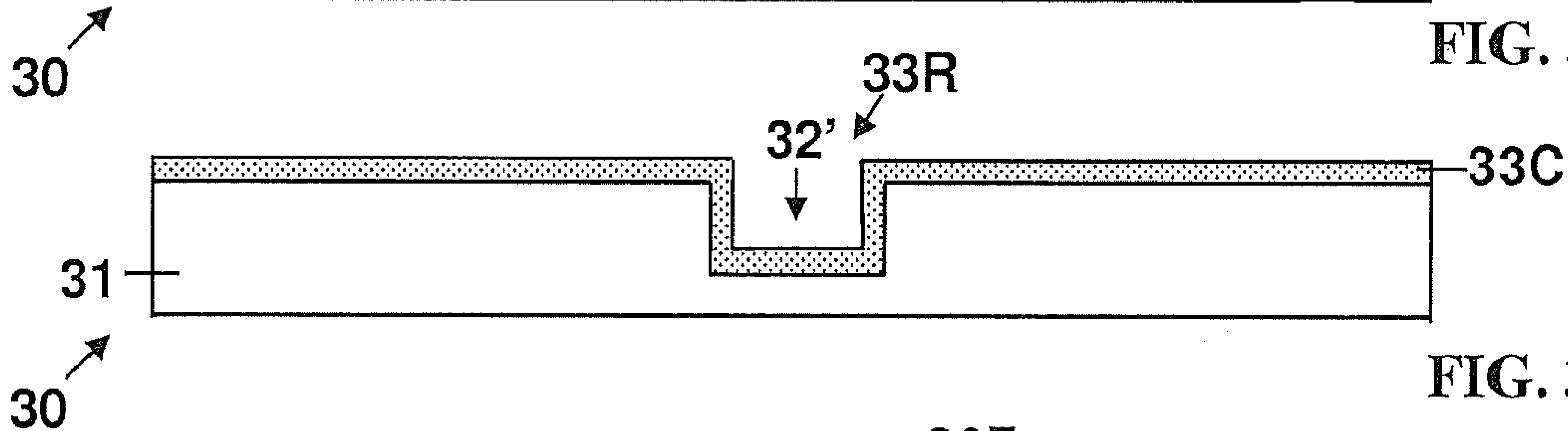


FIG. 3D

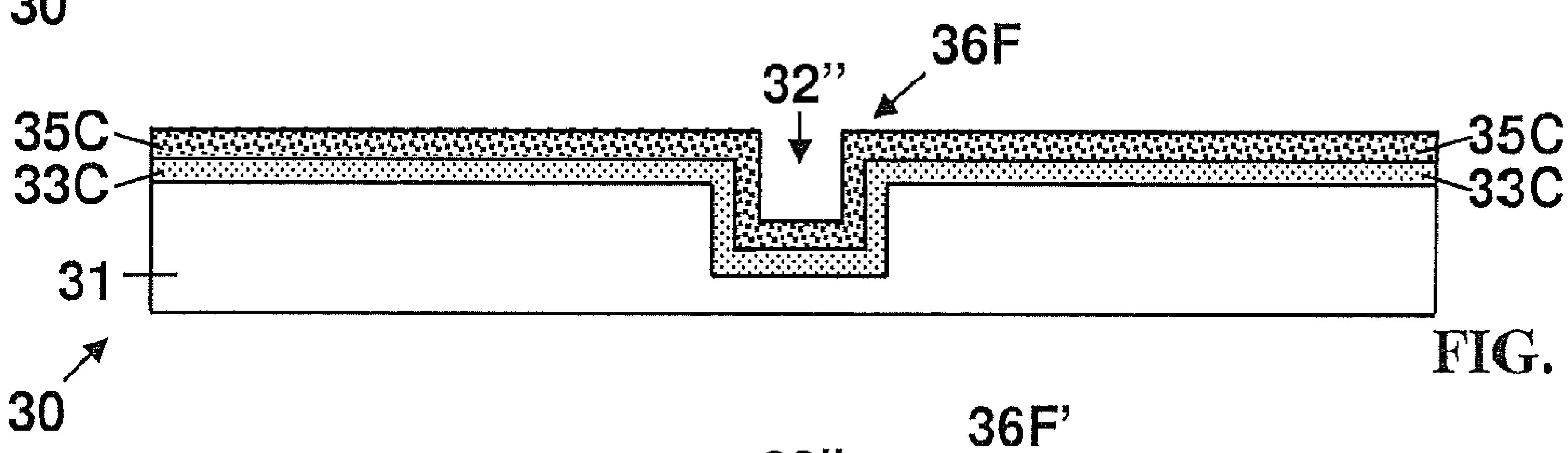


FIG. 3E

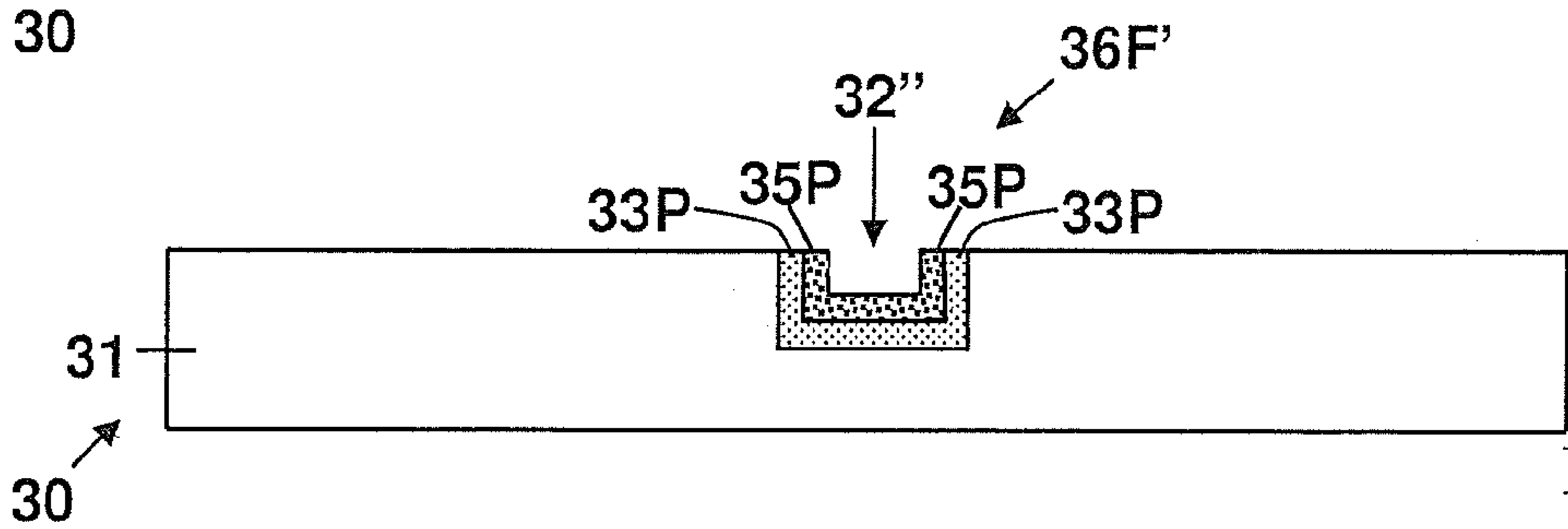


FIG. 3F

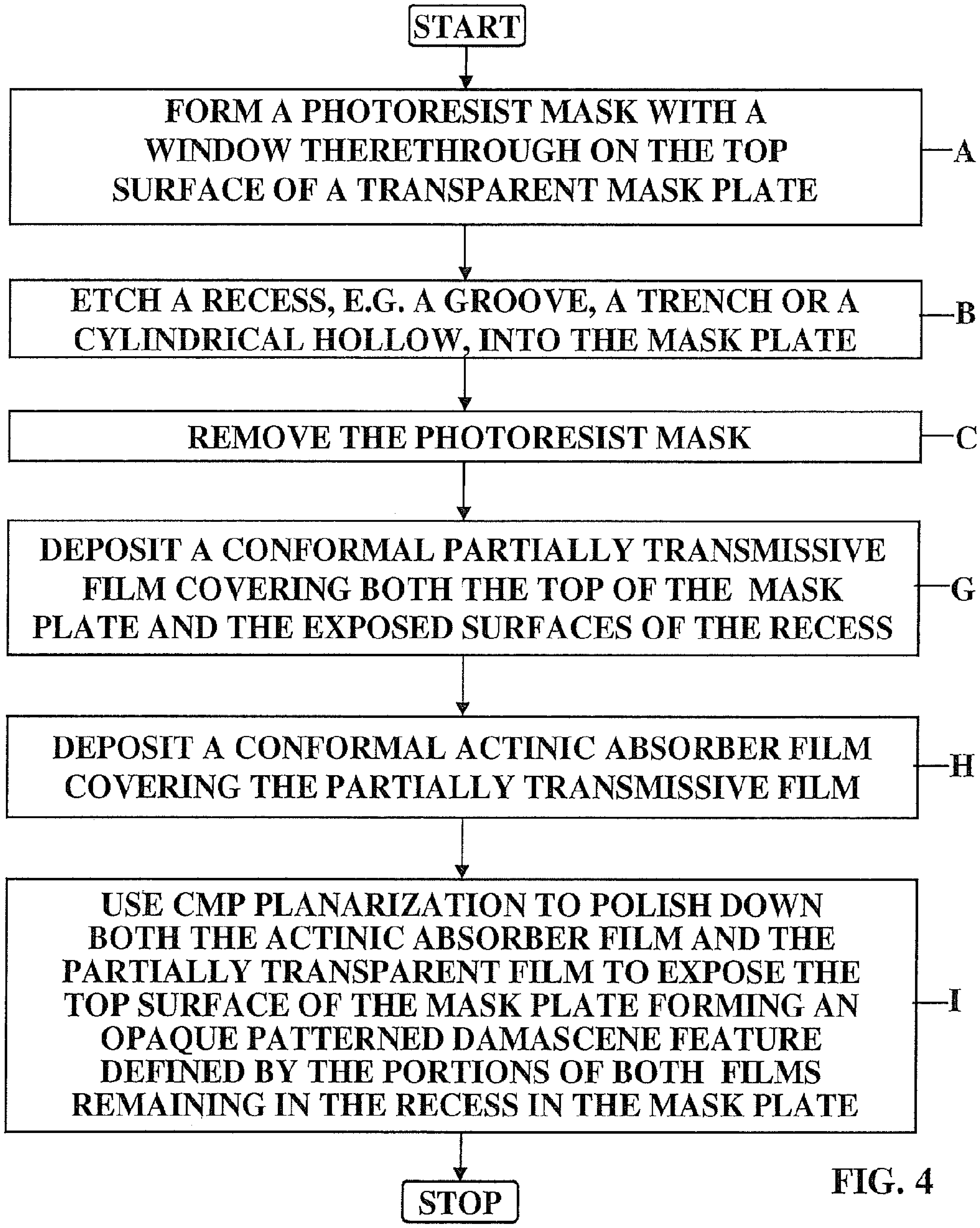

START
FORM A PHOTORESIST MASK WITH A WINDOW THERETHROUGH ON THE TOP SURFACE OF A TRANSPARENT MASK PLATE
A
ETCH A RECESS, E.G. A GROOVE, A TRENCH OR A CYLINDRICAL HOLLOW, INTO THE MASK PLATE
B
REMOVE THE PHOTORESIST MASK
C
DEPOSIT A CONFORMAL PARTIALLY TRANSMISSIVE FILM COVERING BOTH THE TOP OF THE MASK PLATE AND THE EXPOSED SURFACES OF THE RECESS
G
DEPOSIT A CONFORMAL ACTINIC ABSORBER FILM COVERING THE PARTIALLY TRANSMISSIVE FILM
H
USE CMP PLANARIZATION TO POLISH DOWN BOTH THE ACTINIC ABSORBER FILM AND THE PARTIALLY TRANSPARENT FILM TO EXPOSE THE TOP SURFACE OF THE MASK PLATE FORMING AN OPAQUE PATTERNED DAMASCENE FEATURE DEFINED BY THE PORTIONS OF BOTH FILMS REMAINING IN THE RECESS IN THE MASK PLATE
I
STOP

FIG. 4

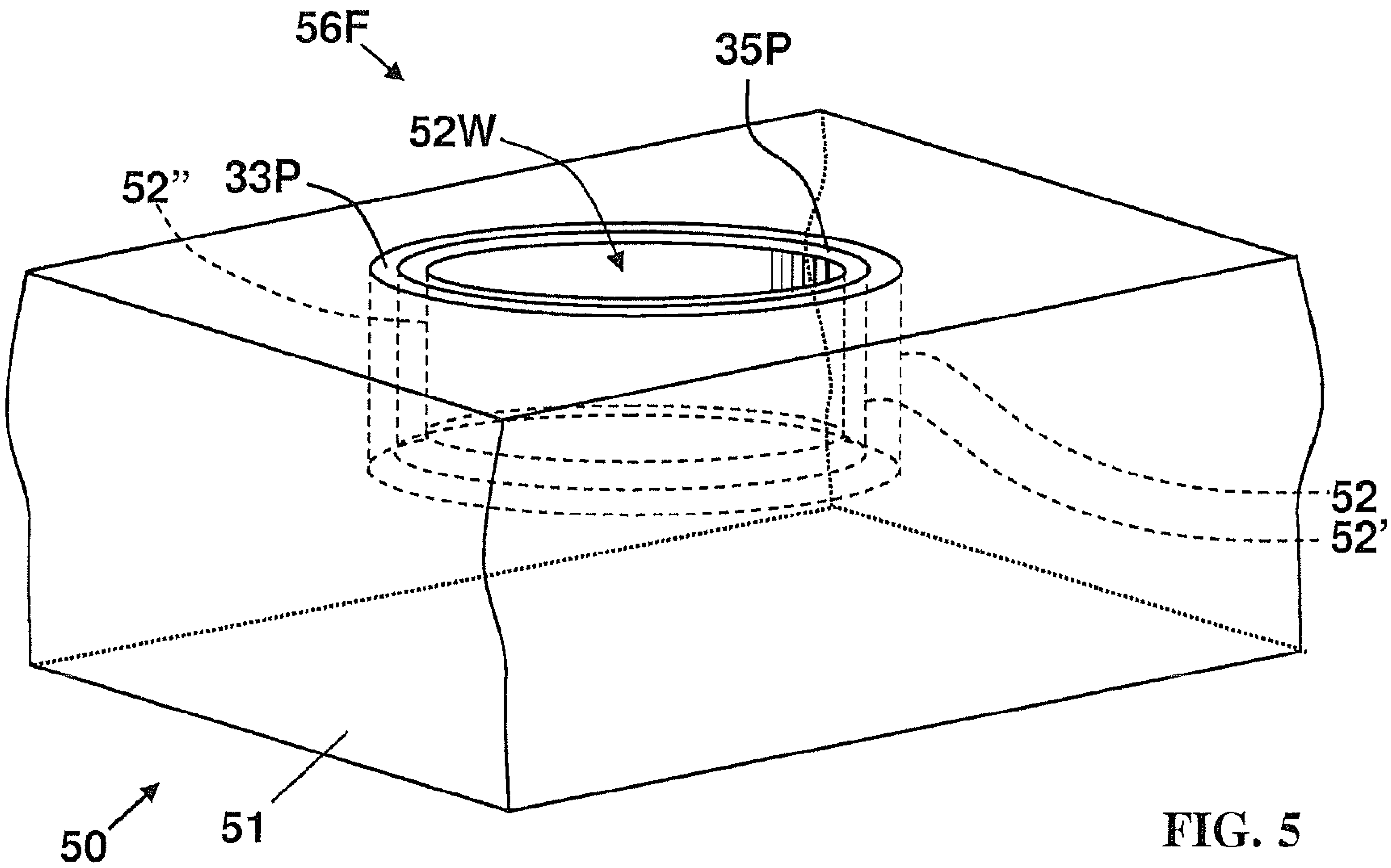
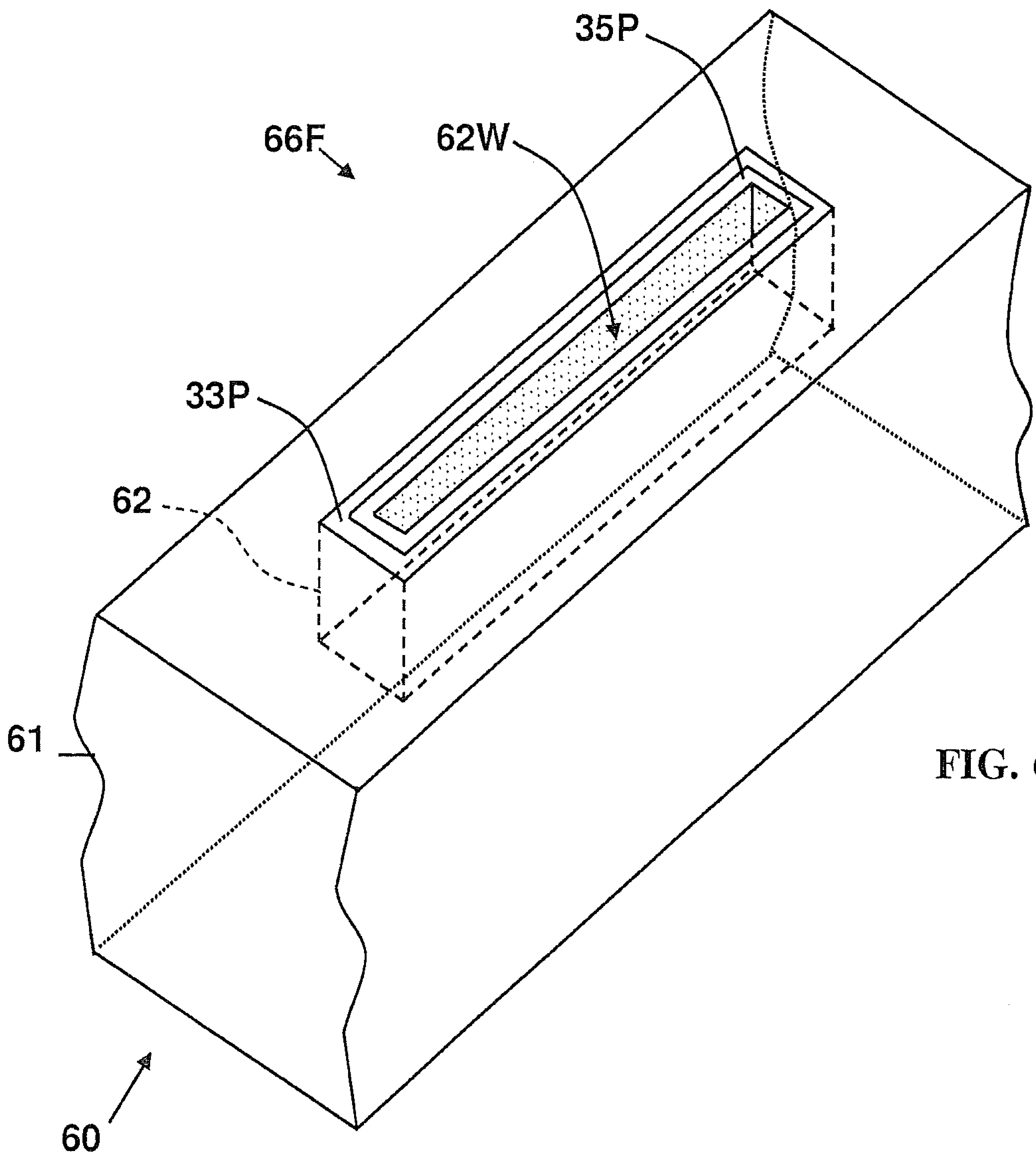


FIG. 5

TRANSPARENT MATERIAL	REFRACTIVE INDEX
CaF_2	1.434
BaF_2	1.474
glass	1.5-1.9
synthetic quartz (fused silica)	1.458
crystalline quartz	1.544 (n_o), 1.553 (n_e)
calcite	1.658 (n_o), 1.486 (n_e)
sapphire	1.769
diamond	2.417
silicon	3.478 (1.55μm)
ZnSe	2.624 2.403 (10.6 μm)

FIG.18



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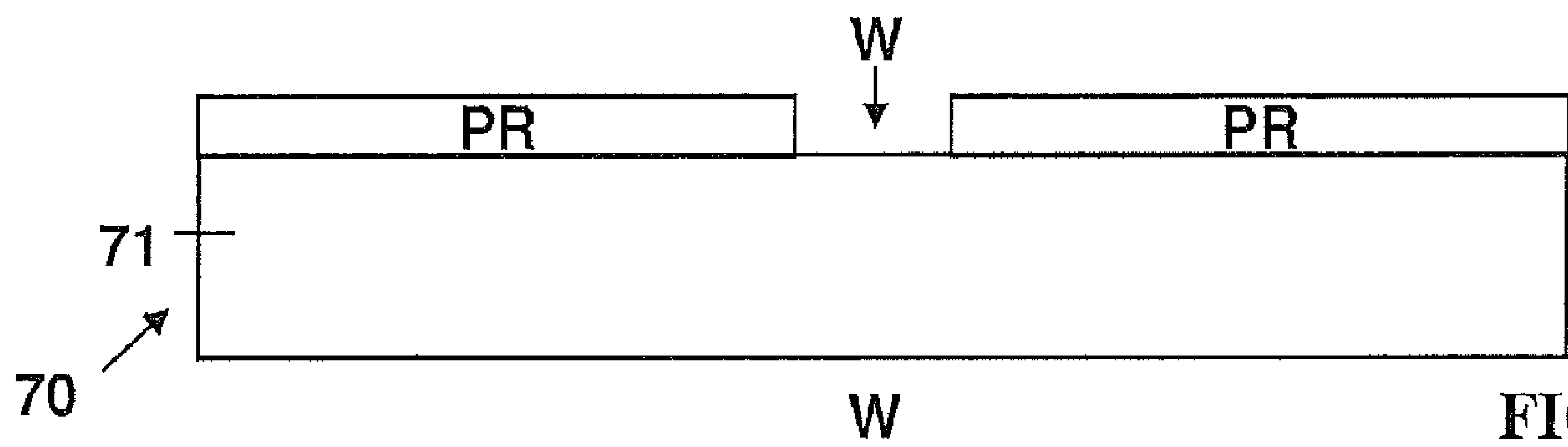

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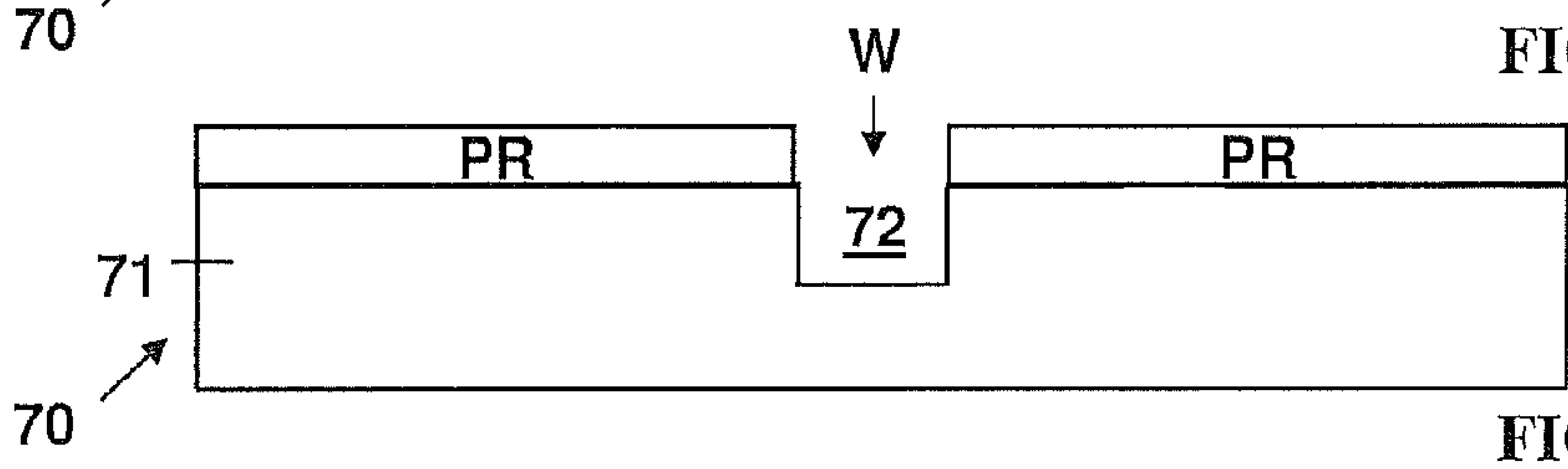

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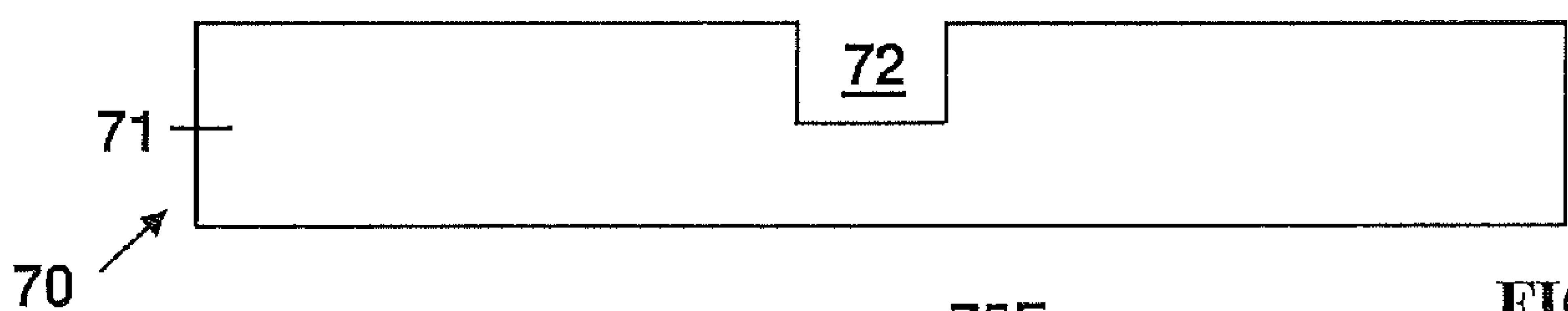


FIG. 7C

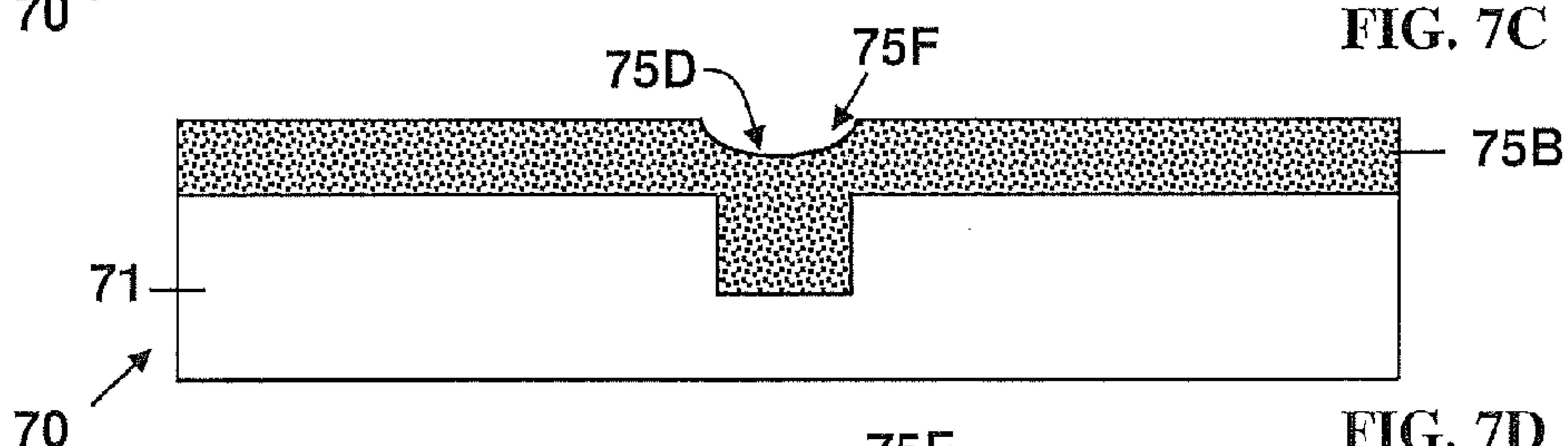


FIG. 7D

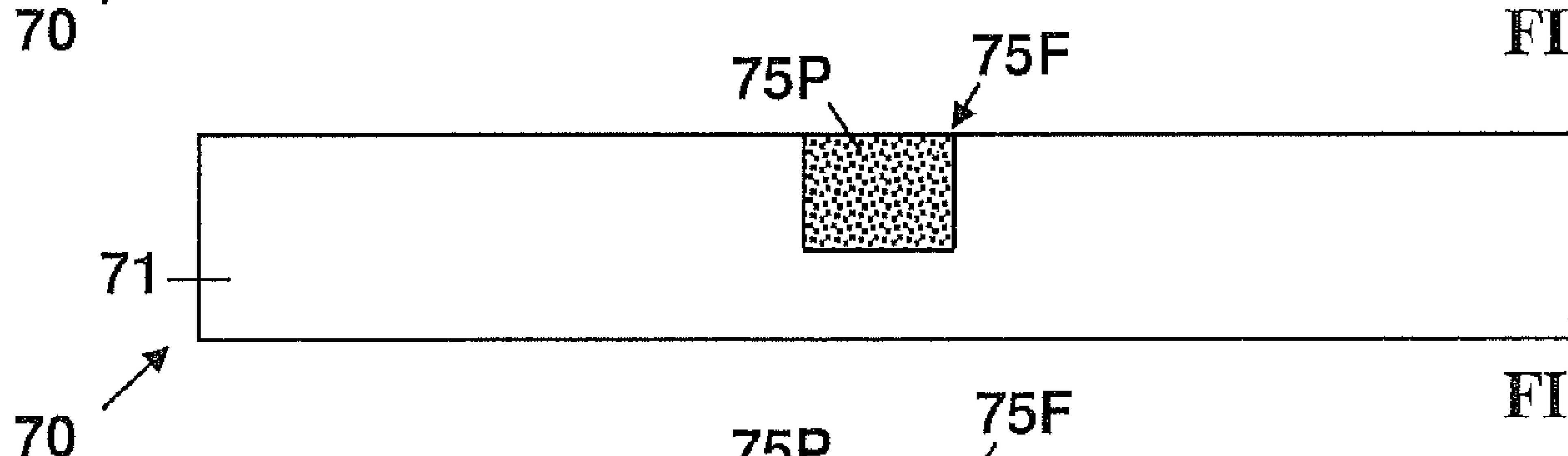


FIG. 7E

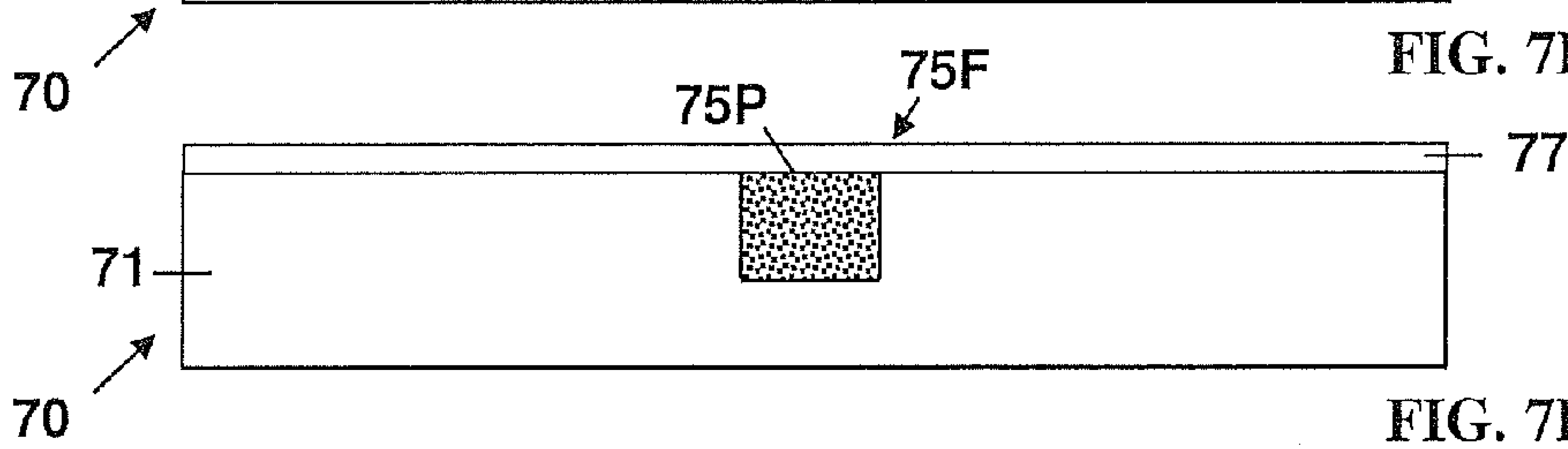


FIG. 7F

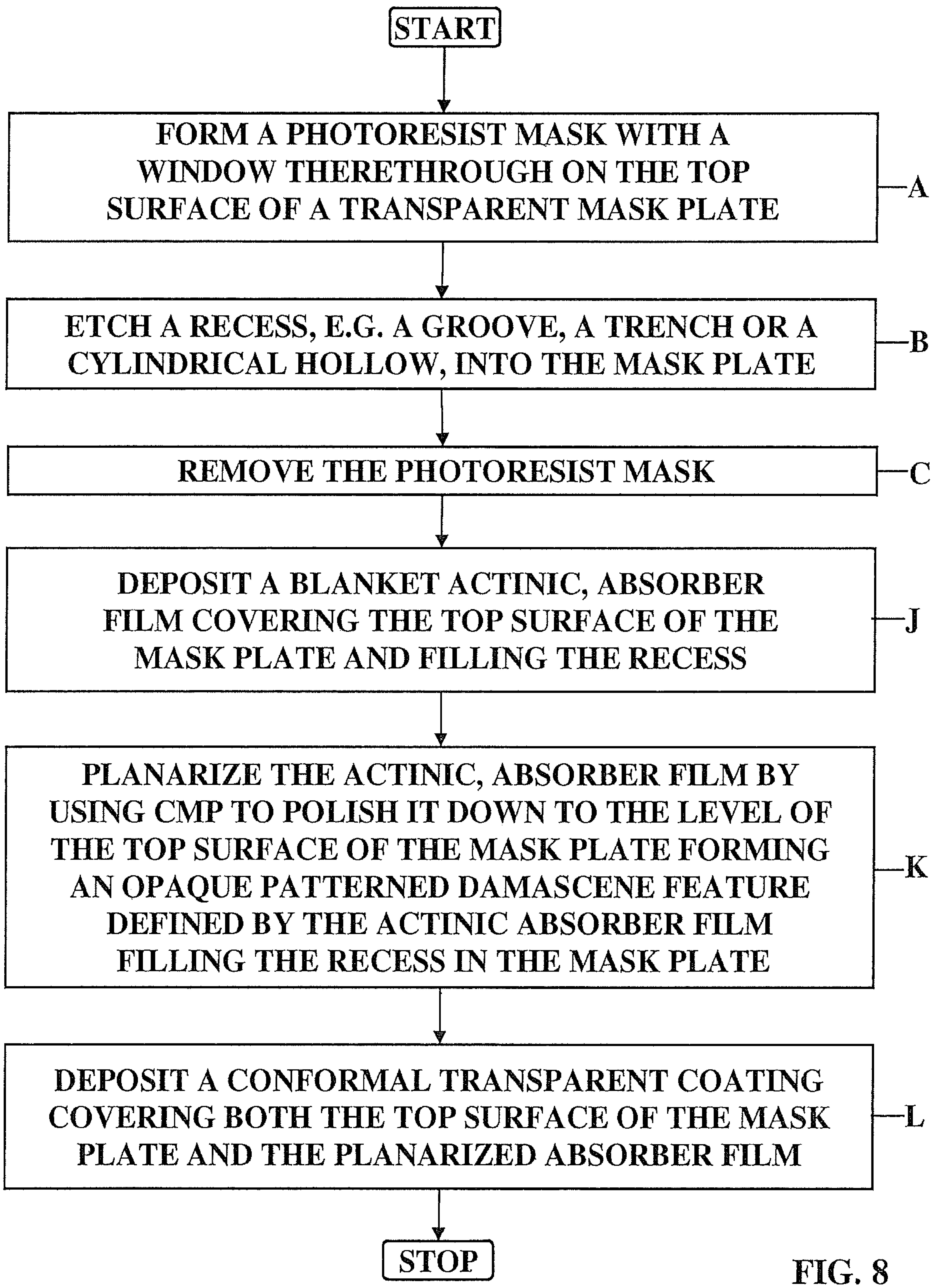

START
FORM A PHOTORESIST MASK WITH A WINDOW THERETHROUGH ON THE TOP SURFACE OF A TRANSPARENT MASK PLATE
A
ETCH A RECESS, E.G. A GROOVE, A TRENCH OR A CYLINDRICAL HOLLOW, INTO THE MASK PLATE
B
REMOVE THE PHOTORESIST MASK
C
DEPOSIT A BLANKET ACTINIC, ABSORBER FILM COVERING THE TOP SURFACE OF THE MASK PLATE AND FILLING THE RECESS
J
PLANARIZE THE ACTINIC, ABSORBER FILM BY USING CMP TO POLISH IT DOWN TO THE LEVEL OF THE TOP SURFACE OF THE MASK PLATE FORMING AN OPAQUE PATTERNED DAMASCENE FEATURE DEFINED BY THE ACTINIC ABSORBER FILM FILLING THE RECESS IN THE MASK PLATE
K
DEPOSIT A CONFORMAL TRANSPARENT COATING COVERING BOTH THE TOP SURFACE OF THE MASK PLATE AND THE PLANARIZED ABSORBER FILM
L
STOP

FIG. 8

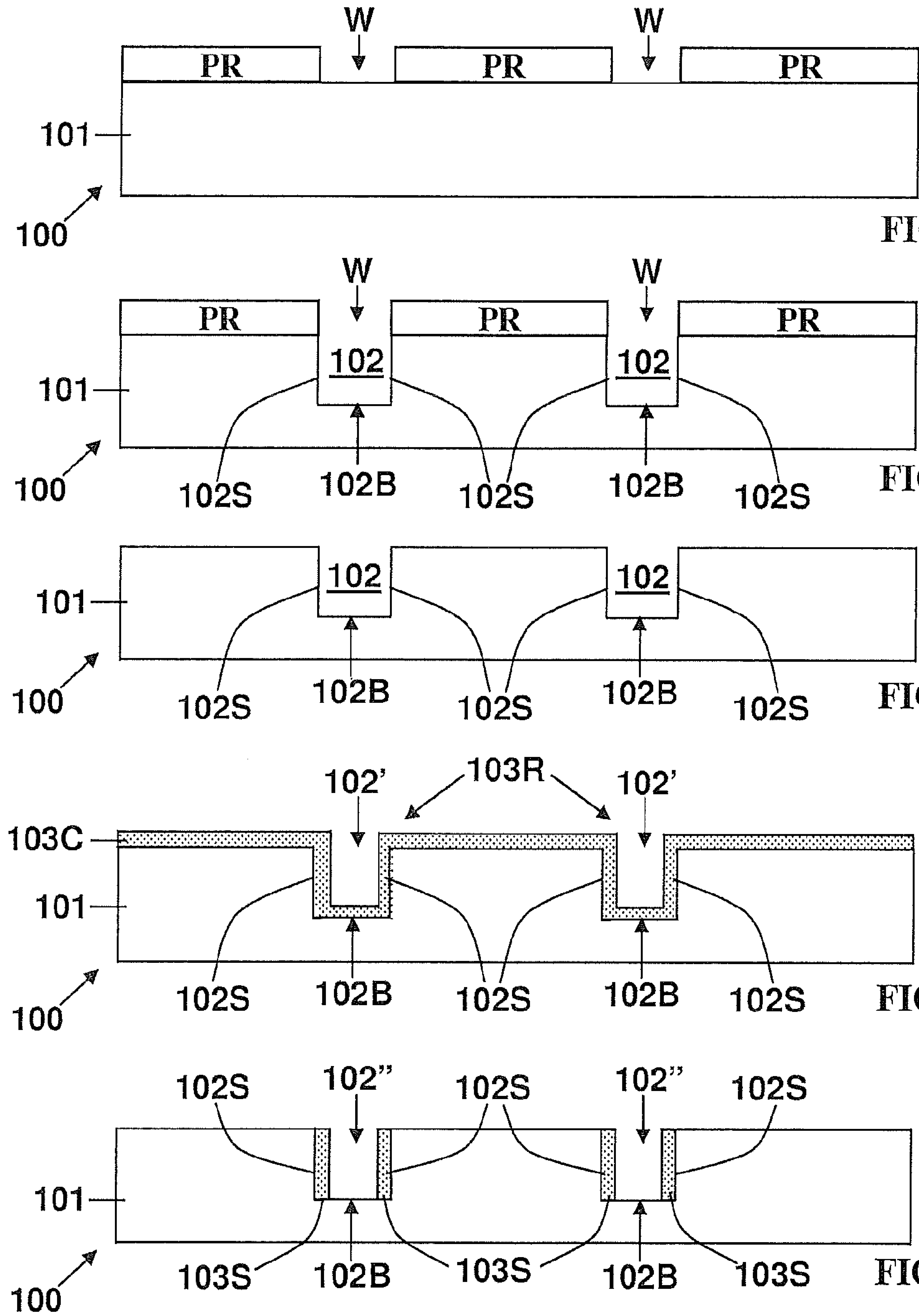


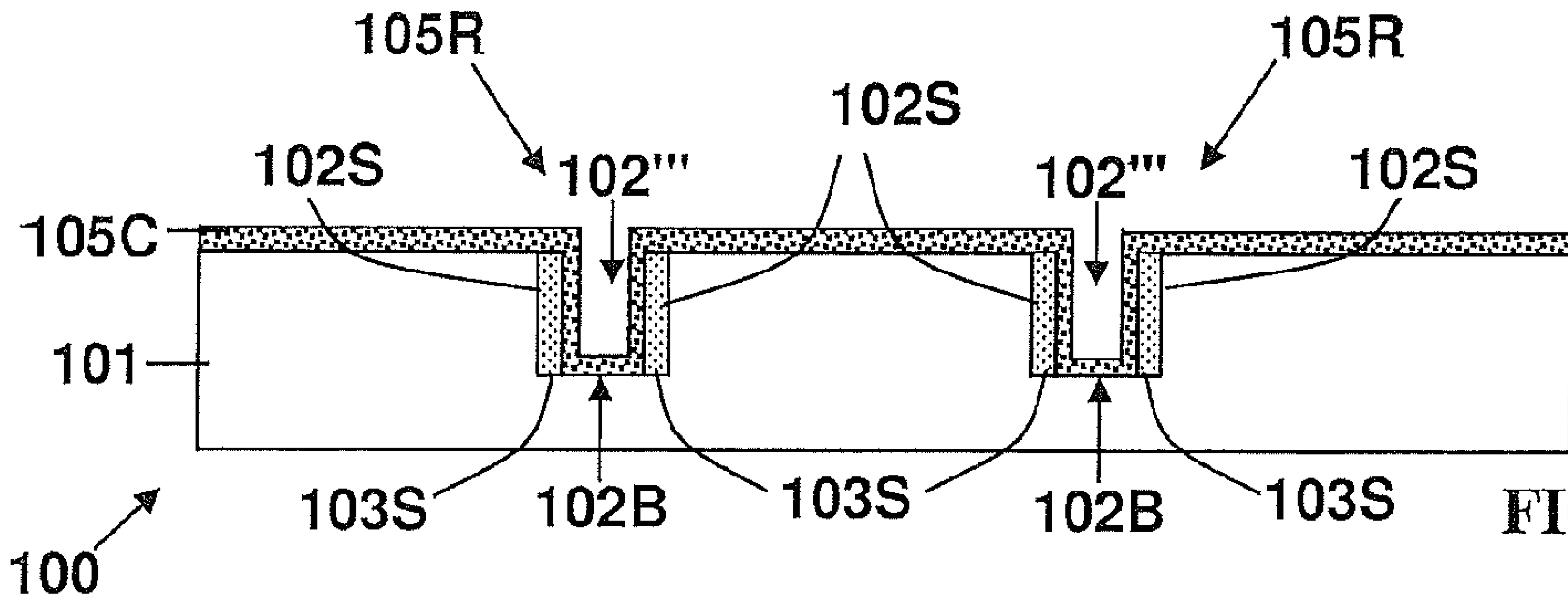
FIG. 9A

FIG. 9B

FIG. 9C

FIG. 9D

FIG. 9E



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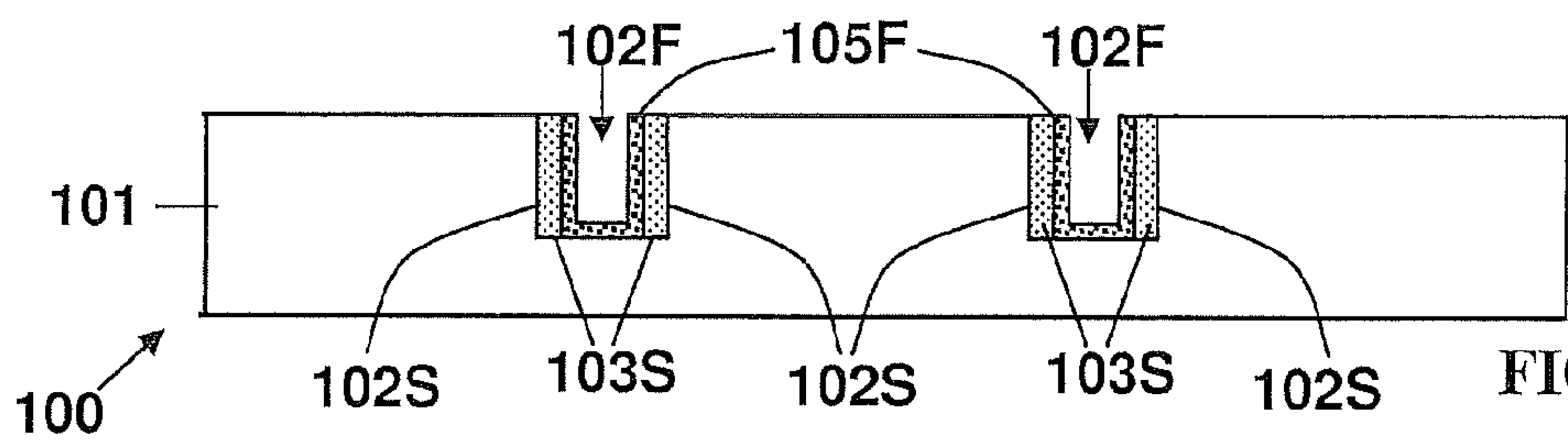


FIG. 9G

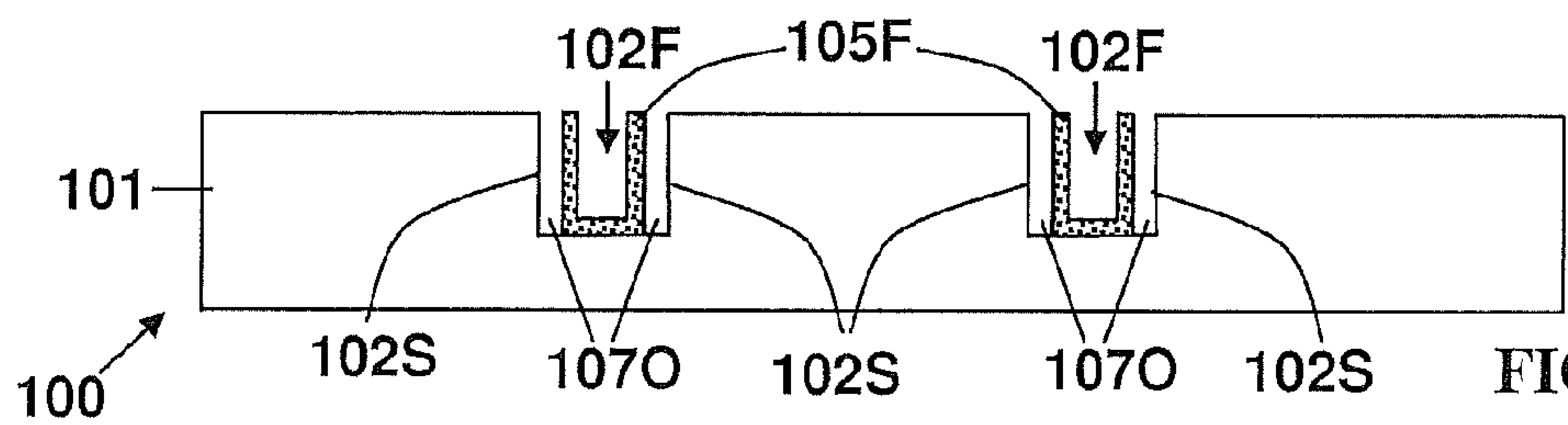


FIG. 9H

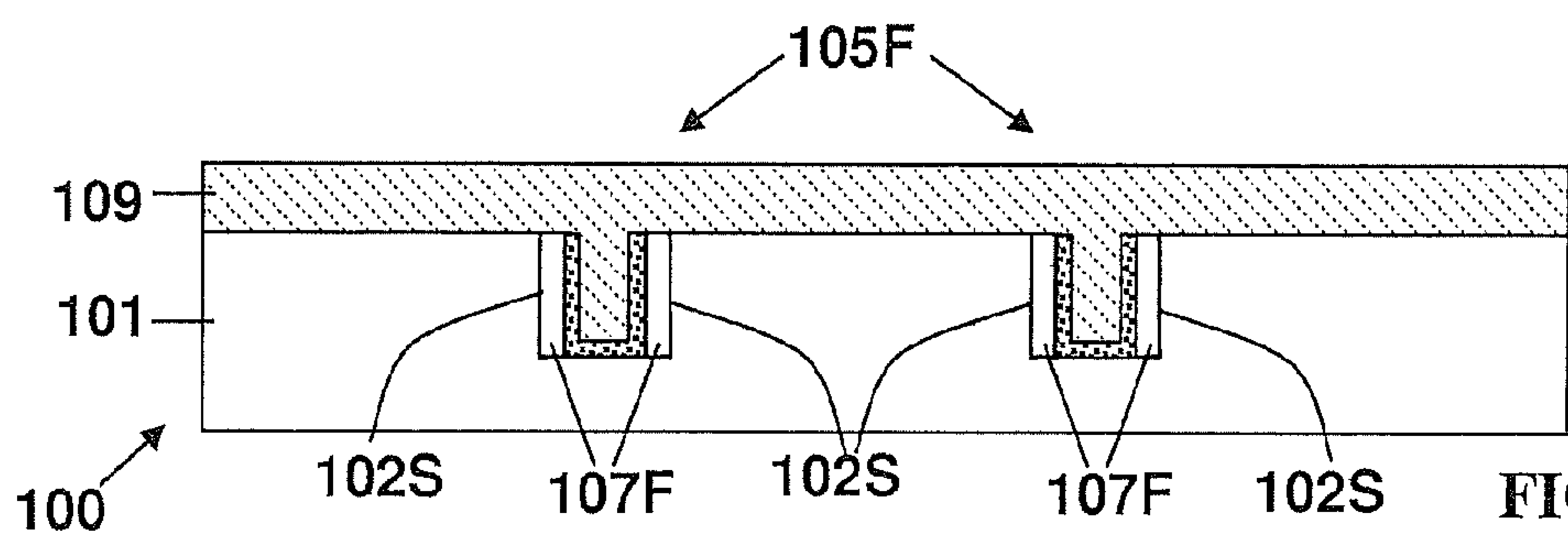


FIG. 9I

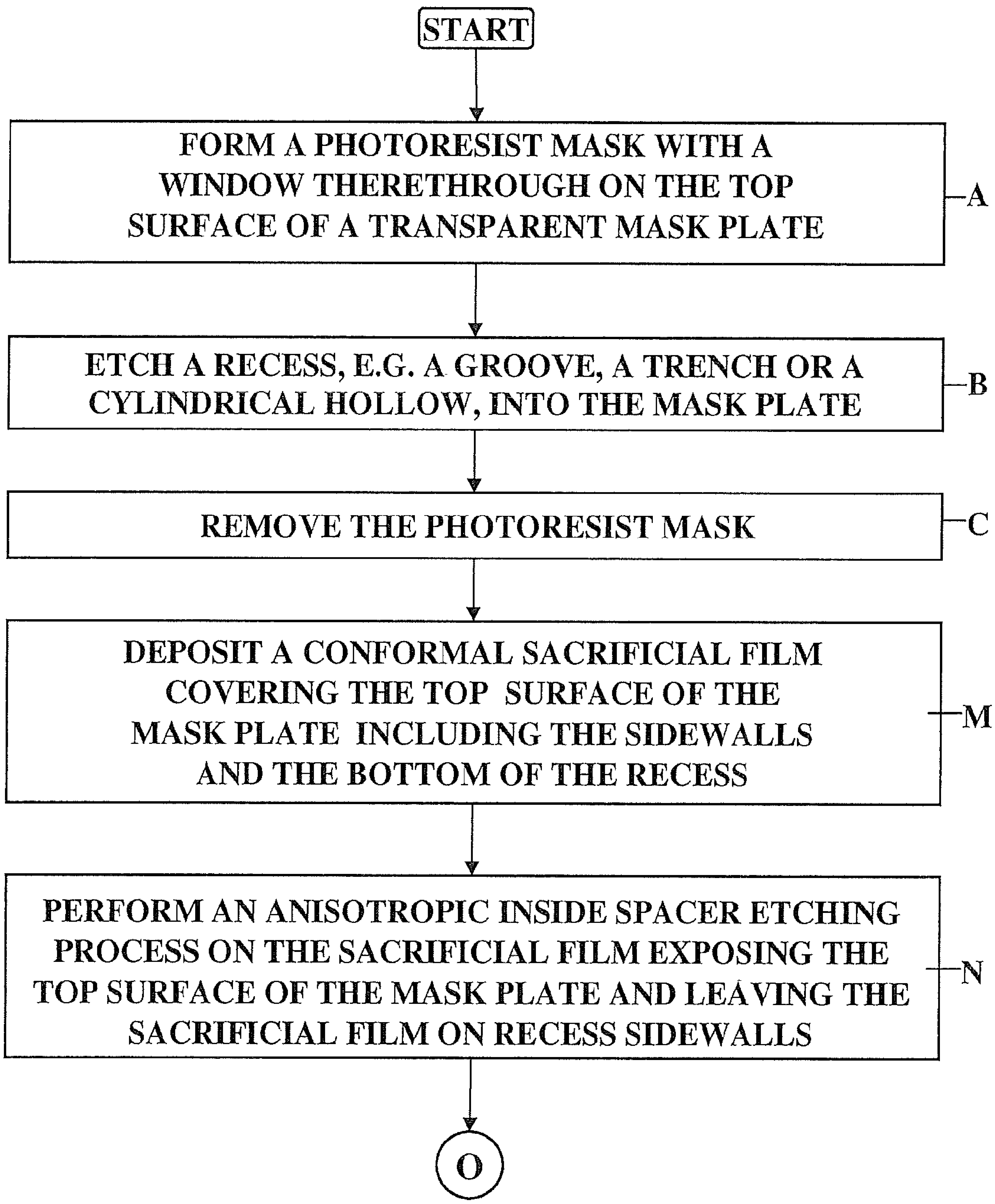
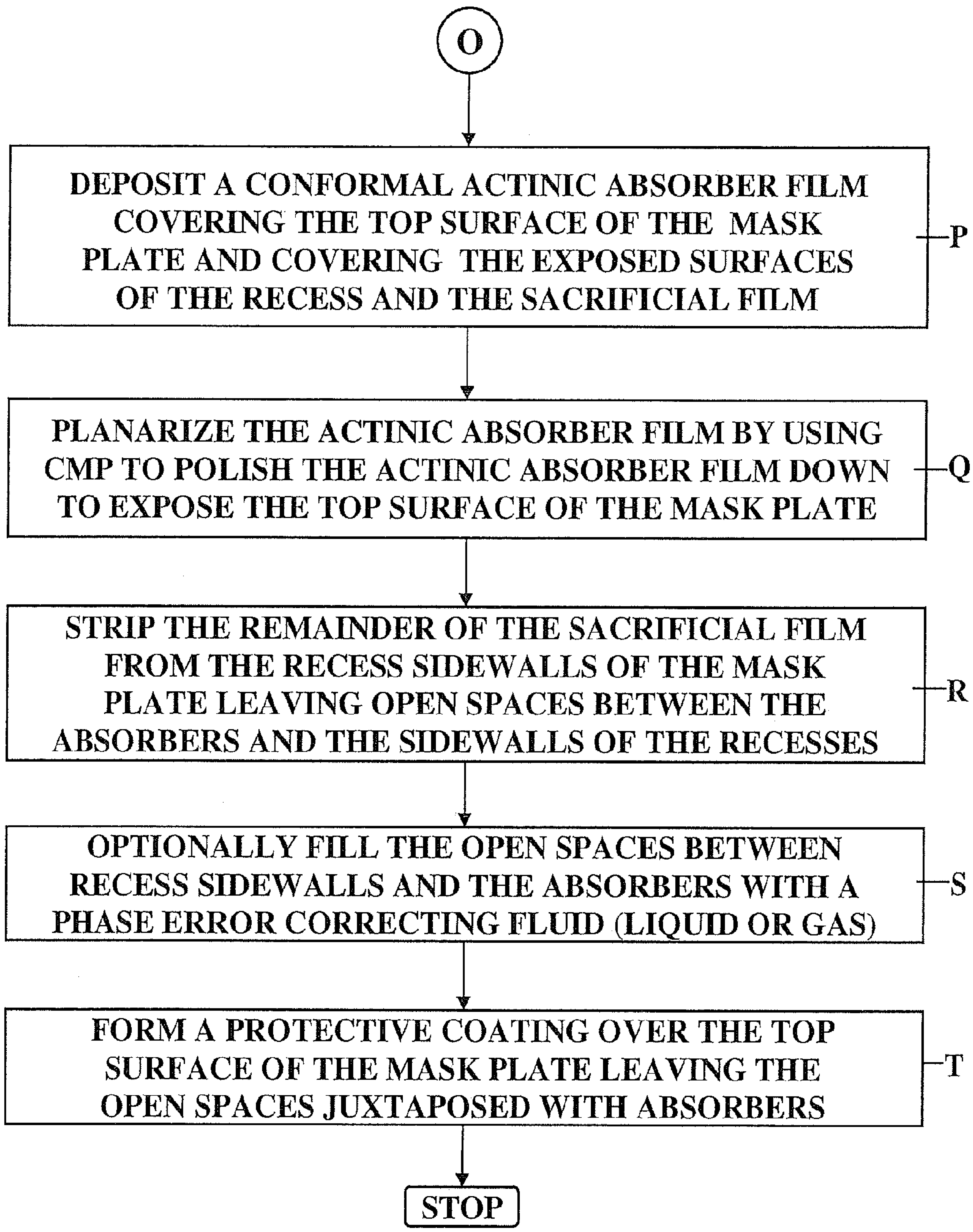

START
FORM A PHOTORESIST MASK WITH A WINDOW THERETHROUGH ON THE TOP SURFACE OF A TRANSPARENT MASK PLATE
A
ETCH A RECESS, E.G. A GROOVE, A TRENCH OR A CYLINDRICAL HOLLOW, INTO THE MASK PLATE
B
REMOVE THE PHOTORESIST MASK
C
DEPOSIT A CONFORMAL SACRIFICIAL FILM COVERING THE TOP SURFACE OF THE MASK PLATE INCLUDING THE SIDEWALLS AND THE BOTTOM OF THE RECESS
M
PERFORM AN ANISOTROPIC INSIDE SPACER ETCHING PROCESS ON THE SACRIFICIAL FILM EXPOSING THE TOP SURFACE OF THE MASK PLATE AND LEAVING THE SACRIFICIAL FILM ON RECESS SIDEWALLS
N
O

FIG. 10A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DEPOSIT A CONFORMAL ACTINIC ABSORBER FILM COVERING THE TOP SURFACE OF THE MASK PLATE AND COVERING THE EXPOSED SURFACES OF THE RECESS AND THE SACRIFICIAL FILM
P
PLANARIZE THE ACTINIC ABSORBER FILM BY USING CMP TO POLISH THE ACTINIC ABSORBER FILM DOWN TO EXPOSE THE TOP SURFACE OF THE MASK PLATE
Q
STRIP THE REMAINDER OF THE SACRIFICIAL FILM FROM THE RECESS SIDEWALLS OF THE MASK PLATE LEAVING OPEN SPACES BETWEEN THE ABSORBERS AND THE SIDEWALLS OF THE RECESSES
R
OPTIONALLY FILL THE OPEN SPACES BETWEEN RECESS SIDEWALLS AND THE ABSORBERS WITH A PHASE ERROR CORRECTING FLUID (LIQUID OR GAS)
S
FORM A PROTECTIVE COATING OVER THE TOP SURFACE OF THE MASK PLATE LEAVING THE OPEN SPACES JUXTAPOSED WITH ABSORBERS
T
STOP

FIG. 10B

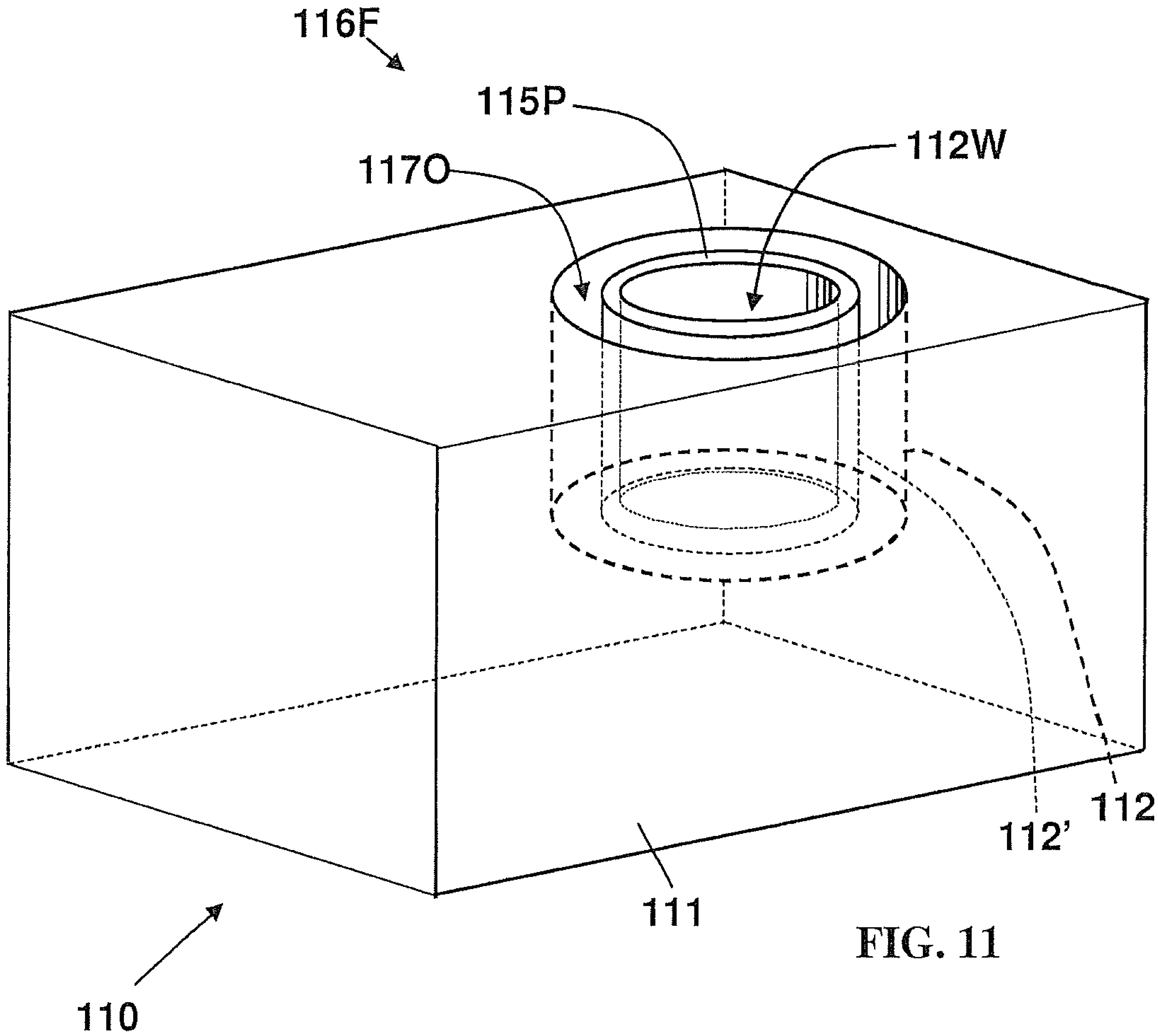

FIG. 11

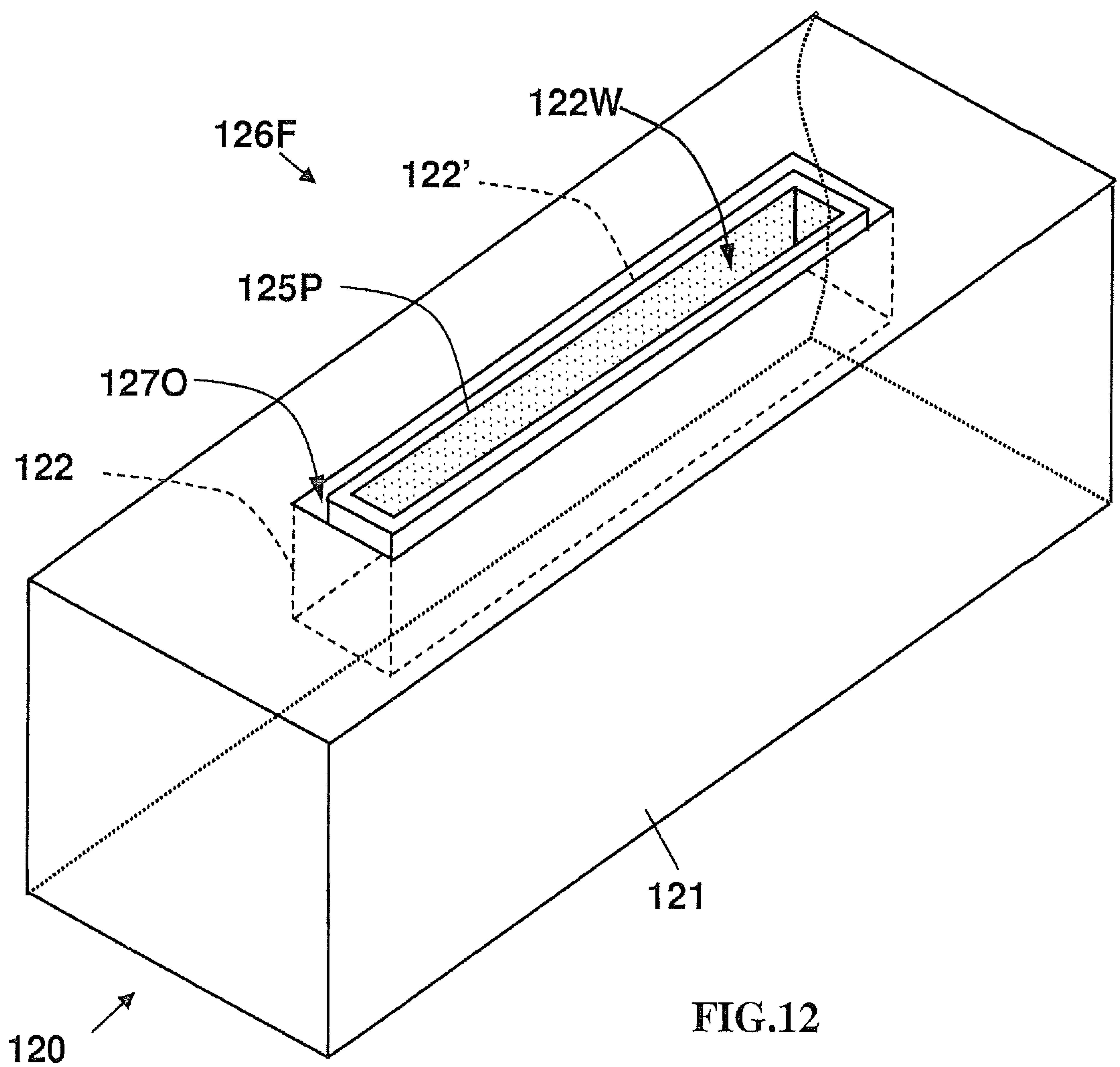

FIG.12

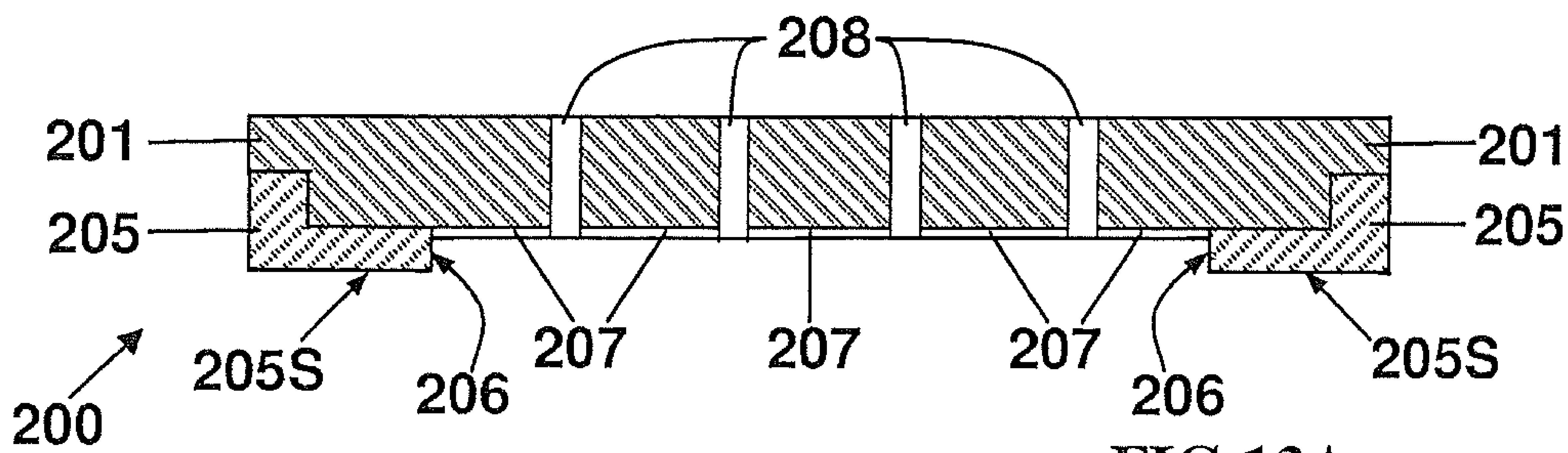

FIG.13A

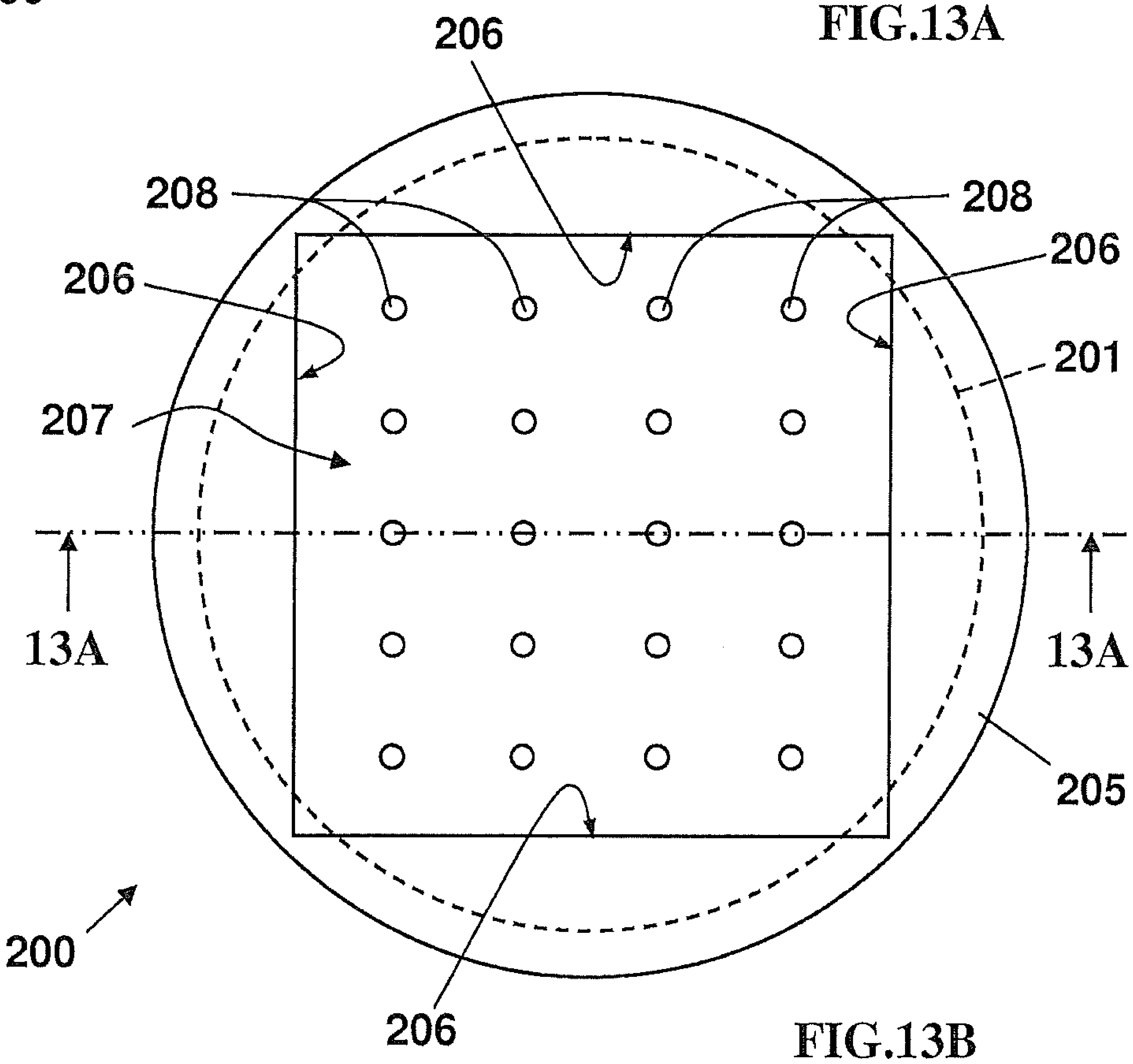

FIG.13B

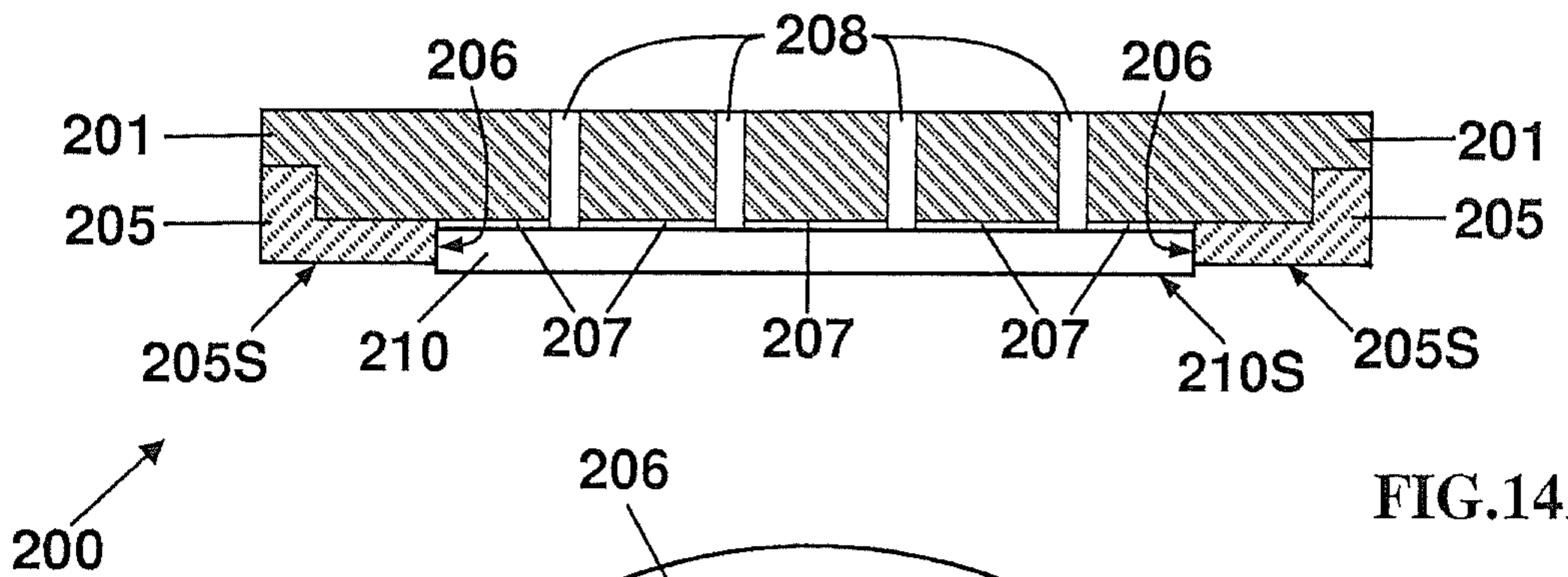

FIG.14A

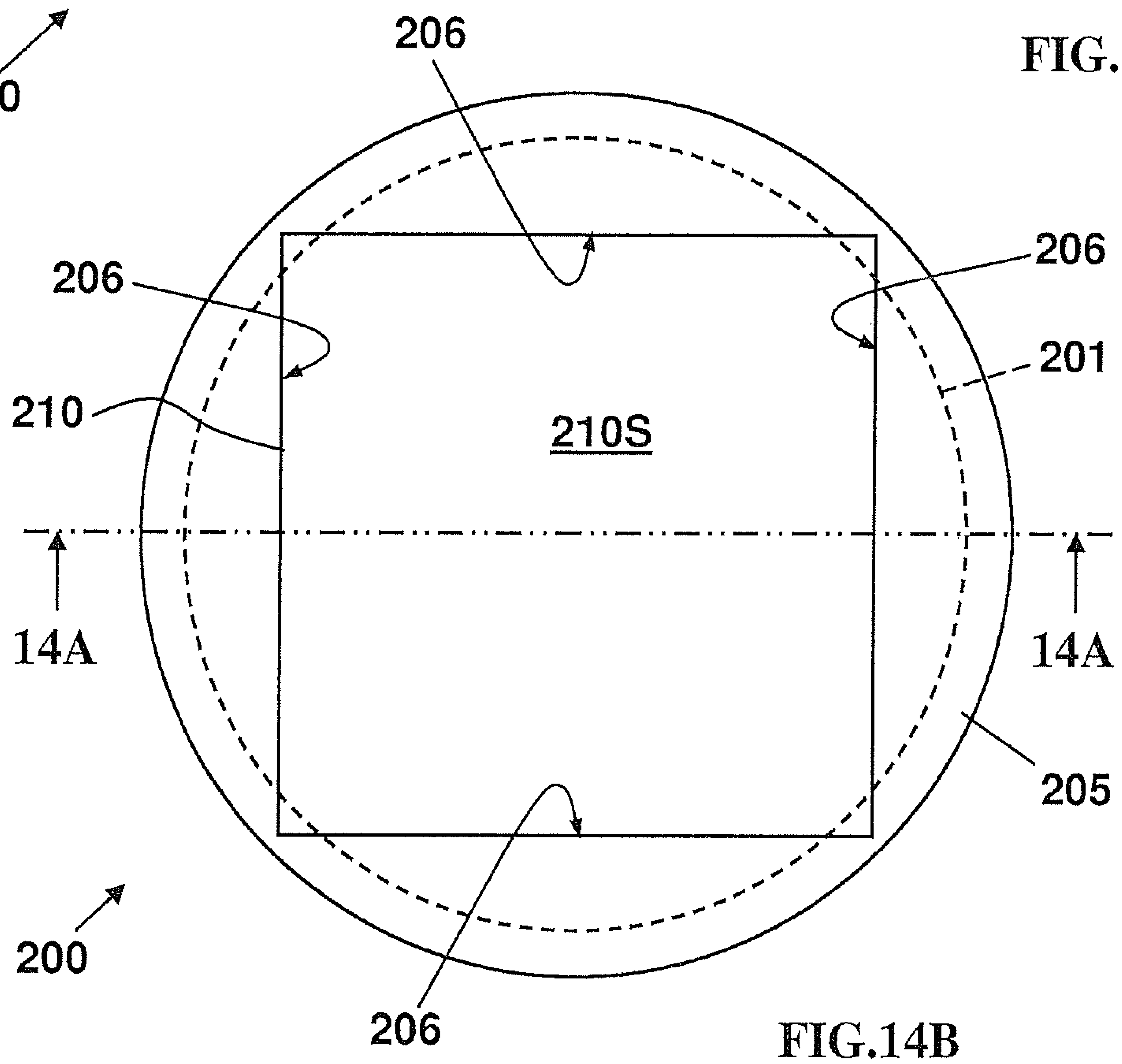

FIG.14B

COLLOIDALLY GROWN SILICA	ACID STABILIZED, PARTICLE SIZE 20-200nm, SOLID LOADING 2-20%
HYDROGEN PEROXIDE	30% SOLUTION, ADDED AT A CONCENTRATION OF 2-50 ml/L
CORROSION INHIBITOR	0.1-10 g/L
POLYACRYLIC ACID	MW 2000, 0.1-10 g/L
OXIDE POLISH RATE INHIBITOR	0.1-10 ml/L
WATER	ADD ENOUGH WATER TO BRING TO VOLUME

FIG.15

SLURRY	COMMERCIALLY AVAILABLE FUMED SILICA STABILIZED AT ALKALINE pH (pH RANGE 9-12)
pH	ADJUSTED TO 2.4 (RANGE 2.2-2.6)
SOLUTION FOR pH ADJUSTMENT	10X DILUTION IN WATER OF 86 PERCENT PHOSPHORIC ACID (1 PART ACID TO 9 PARTS PHOSPHORIC ACID)

FIG.16

POLISHING TOOL	WESTECH
PAD	CONVENTIONAL URETHANE TOP PAD (IC1000), NON-WOVEN SUBPAD (SUBA IV)
SLURRY FLOW	150 ml/min (RANGE 75- 250 ml/min)
DOWNFORCE	3 psi, (RANGE 1-8 psi)
SPEED	25 rpm PLATEN, 50 rpm CARRIER (SPEED RATIO SHOULD BE ADJUSTED FOR BEST UNIFORMITY)
WAFER BACKSIDE PRESSURE	2 PSI; ADJUSTED FOR OPTIMUM UNIFORMITY
PAD CONDITIONING	DIAMOND GRIT, 70 MICRON, 0.5 psi, for 45 SECONDS AFTER EACH POLISH

FIG.17

RETICLE CARRIER

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is a divisional of U.S. application Ser. No. 13/278,571, filed on Oct. 21, 2011, which is a divisional of U.S. Pat. No. 8,110,321 filed on May 16, 2007, the disclosures of which are incorporated herein by reference.

BACKGROUND

The present application relates to methods of manufacture of photolithographic reticles, i.e. masks, and reticles produced thereby. More particularly the present application relates to methods for fabrication of reticles for exposure of microelectronic integrated circuits and other micro-scale devices and to the reticles produced thereby.

During the process of manufacturing of microelectronic integrated circuits on a substrate comprising a workpiece such as a semiconductor wafer or the like, layers of material on the workpiece are patterned photolithographically. A layer of a radiation sensitive resist (hereinafter resist) is deposited on the workpiece. The resist (e.g. photoresist) comprises a radiation sensitive material which can be exposed to a master image projected as patterns of radiation, e.g. light, ultraviolet light, x-ray, electron beam, or other forms of radiation. The resist is later exposed using an exposure tool and a reticle. The reticle comprises a photomask or the like which is patterned with opaque regions, transparent regions and possibly partially transparent regions. During the exposure process, radiation is directed onto the reticle to expose the resist selectively with patterns of radiation projected through the reticle.

The resist is developed, and then the remaining resist forms a mask on the workpiece which protects areas of the workpiece during subsequent fabrication processes, such as deposition, etching, or ion implantation. A mask or photomask is generally used for photoimaging with a positive or negative image when exposing a photosensitive material known as photoresist or analogous materials sensitive to electromagnetic or other forms of radiation.

Binary Reticle

A binary reticle includes a pattern corresponding to features to be formed on work pieces such as FET devices or other Integrated Circuit (IC) features. A binary reticle may be formed on a reticle mask plate comprising a transparent glass plate coated with a patterned, opaque (light blocking) material. This type of reticle is typically referred to as a binary mask since some of the light is completely blocked by the opaque material and the remainder of the light is fully transmitted through the transparent, glass portions.

Chrome on Glass (COG) Binary Reticle

A Chrome-On-Glass (COG) reticle (i.e. a mask, photomask, or photoreticle) typically comprises a quartz-chrome patterned mask. In more detail, a COG reticle comprises a single crystal quartz reticle mask plate that is substantially planar, which carries a mask pattern defined using a patterned chrome (Cr/CrO_2) layer, formed by sputtering. The chrome layer is laminated to the top surface of the reticle mask plate. A virgin or blank COG reticle mask plate or mask blank comprises a virgin reticle which has not been patterned. In other words, a virgin COG reticle comprises an unpatterned or blank planar layer of chrome deposited on a quartz reticle mask plate.

In the production of a COG patterned reticle, e.g. an Integrated Circuit Device (ICD), an image of one or more microelectronic devices is printed onto a virgin COG reticle via a lithographic process by exposure to radiation. A layer of resist is applied to the blank COG reticle mask plate covering the top surface of the chrome layer. After patterning by exposure of the resist to a master image, the resist is developed to reproduce the exposed pattern thereby producing openings down to the surface of the chrome of the COG mask. Exposed surfaces of the COG mask are removed by etching leaving the remaining portions of the chrome layer intact. Then the resist is removed with appropriate chemicals and washed away.

In the context of photolithography, the term reticle refers to a semiconductor photomask, which contains an image which is adapted to expose only a small part of a semiconductor wafer which is to be employed in a step-and-repeat exposure system, i.e. a wafer stepper or scanner. A semiconductor reticle typically contains the pattern of a several semiconductor devices. The reticle is employed in the wafer stepper to project an image to be exposed over and over onto a workpiece comprising a semiconductor wafer covered with unexposed photoresist by moving the workpiece relative to the reticle with the wafer stepper or scanner, which is employed to expose several areas of the unexposed photoresist repeatedly and sequentially.

In addition to visible light, the absorber may be capable of absorbing radiation such as infra-red, x-ray, E-beam, or light in ranges such as the UltraViolet (UV) range, Deep UltraViolet (DUV) range, Vacuum UltraViolet (VUV) range, and Extreme UltraViolet range (EUV).

The present application relates to processing of integrated circuit devices and particularly to the manufacturing of optical projection masks for deep submicron (<0.25.μm) integrated circuit processes.

A common method of manufacturing of projection reticles for exposure of integrated circuit devices has relied on etching a pattern into an actinic radiation absorber comprising a layer of absorbent material which is deposited on a reticle mask plate (i.e. a transparent substrate or mask blank.) Currently in semiconductor fabrication the patterning of structures on a substrate is often performed with reticles defined by lithography performed on a blank COG reticle.

There is a serious problem with the process of etching through the chrome of a COG reticle mask plate down to the quartz therebelow which is that the etching process for the chrome also consumes the photoresist mask very quickly which forces certain restrictions in the mask making process (e.g. resist thickness.)

There are other serious problems with etched COG reticles. One such problem with etched COG reticles is that Electro-Static Discharge (ESD) can cause damage to the metal (chrome) pattern on a substrate composed of quartz as the insulating material. The problem is that unwanted Electro-Static Discharge (ESD), involving rapid dissipation of electric charge in a short amount of time, often causes delamination of the chrome pattern from the quartz substrate. In other words, at least a portion of the chrome pattern on the quartz substrate is lifted away from the top surface thereof, as the ESD energy is being dissipated in the laminated material. That renders the mask defective so that it is not useful for the fabrication of devices on semiconductor substrates.

Another serious problem with COG reticles is that they grow defects over the lifetime of the mask which limits the useful lifetime of such reticles and forces regular cleaning.

Phase Shift Mask (PSM)

Another type of reticle is the Phase Shift Mask (PSM), which can be produced by allowing some light to pass through a partially-transmissive chrome feature thereby changing the phase of the light that passes therethrough, i.e. creating phase shifted light. The phase shifted light from the partially-transmissive feature affects the interference pattern of the light transmitted from neighboring fully transparent areas, resulting in a higher contrast at the imaging plane. This allows imaging features with significantly smaller feature sizes than would be possible using the same mask pattern implemented as a standard COG reticle. These reticles are referred to as attenuated PSM (AttPSM) reticles.

Alternating PSM (AltPSM) Mask

A third type of reticle is known as an Alternating PSM (AltPSM) reticle (mask) wherein feature recesses are etched into the virgin reticle mask plate. The feature recesses result in a path length difference for the light passing therethrough, and the depth of the feature recess is tuned to result in a 180° phase shift of the incident electromagnetic radiation to be used in exposure of the image on the reticle. The AltPSM mask has limitations in that the termination of features can be difficult and a second mask called a block out has to be used in conjunction therewith to terminate the features that are desired on the substrate. The higher cost of these AltPSM reticle processes is negligible in view of expenses saved as compared to more advanced lithography tooling that would be required when only COG reticles would be used. However the cost of fabrication of a mask set has increased dramatically by introducing those extra processing steps required for AltPSM reticle processing.

Commonly assigned U.S. Pat. No. 5,932,377 of Ferguson et al. entitled "Exact Transmission Balanced Alternating Phase-Shifting Mask for Photolithography" describes forming an AltPSM mask with etched-quartz trenches. It states that a phase difference between two clear shapes for an AltPSM is achieved in standard industry practice by selectively etching into a quartz reticle mask plate so an optical path difference equivalent to the desired phase offset is obtained between two adjacent openings. After standard mask patterning, a second write step is used to selectively open a protective resist coating for a phase-shifted opening leaving a non-phase shifted opening covered. Typically, the quartz is then etched with an anisotropic Reactive-Ion Etching (RIE) process.

Commonly assigned U.S. Pat. No. 5,565,286 of Lin entitled "Combined Attenuated-Alternating Phase Shifting Mask Structure and Fabrication Methods Therefor" describes a structure and fabrication method for a phase-shifting lithographic mask. AltPSM and AltPSM are combined to provide a mask combination consisting of phase-shifted and unshifted attenuated backgrounds in which the phase-shifted attenuated background surrounds the unshifted components and the unshifted attenuated background surrounds the phase-shifted components.

U.S. Pat. No. 6,660,653 of Tzu et al. entitled "Dual Trench Alternating Phase Shift Mask Fabrication" describes fabricating a dual-trench AltPSM mask. A chromium layer formed over a quartz layer of the PSM is patterned with deep trenches by dry etching through a photoresist layer. The quartz layer is dry etched through another photoresist layer applied over the chromium layer and patterned according to the deep trenches and the shallow trenches of the AltPSM design using backside exposure to ultraviolet light.

Damascene Patterning

Traditionally, the term damask refers to rich tapestry patterns of damask silk, such as a figured fabric of silk, wool, linen, cotton, or synthetic fibers, with a pattern formed by weaving. An artistic damascene process of metal work involves inlaying metal into trenches in another metal is a process of inlaying different metals into one another, e.g. gold or silver into a darkly oxidized steel background, to produce intricate patterns.

In semiconductor technology, damascene or dual-damascene metal patterning processes have been employed in forming copper interconnects in a dielectric layer, e.g. silicon oxide, for external electrical connections and interconnections of semiconductor devices. The semiconductor damascene process starts by a subtractive process of etching open trenches reaching down into a dielectric layer wherein copper conductor patterns are to be formed. An additive patterning process is employed involving deposition of a conformal barrier layer followed by deposition of a blanket (thick) coating of copper that significantly overfills the trenches. Then, the excess copper is removed by planarization to the level of the top of the insulating layer by Chemical-Mechanical Polishing (CMP). The copper, which remains within the trenches of the insulating layer, comprises a patterned interconnect conductor.

U.S. Pat. No. 6,821,192 of Donohue entitled "Retaining Ring for Use in Chemical Mechanical Polishing" describes a retaining ring for use on a carrier head in a Semiconductor Wafer CMP (SWCMP) apparatus with a bottom surface, an inner surface and an outer surface, and a plurality of recesses on the bottom surface. Each recess includes an inner trailing surface and a slurry capture area. A channel connects the slurry capture area to the inner surface. The inner trailing surface can be configured for fastening thereon an insert tool having a contact edge for abrasively contacting a polishing pad. The Donohue patent states "Integrated circuits are typically formed on substrates, particularly silicon wafers, by the sequential deposition of conductive, semiconductive or insulative layers. After each layer is deposited, the layer is etched to create circuitry features. As a series of layers are sequentially deposited and etched, the outer or uppermost surface of the substrate, i.e., the exposed surface of the substrate, becomes successively less planar. This non-planar outer surface presents a problem for the integrated circuit manufacturer as a non-planar surface can prevent proper focusing of the photolithography apparatus. Therefore, there is a need to periodically planarize the substrate surface to provide a planar surface. Planarization, in effect, polishes away a non-planar, outer surface, whether a conductive, semiconductive, or insulative layer, to form a relatively flat, smooth surface."

Transmissivity, τ and Opacity

Transmissivity in the context of this invention is defined as the fraction of incident radiation (at actinic wavelength) that passes through a mask, more specifically, a mask plate or combination of materials in or on the mask plate. In the context of this invention a material is considered to be transparent if it has a maximum value of transmissivity equal to that of the mask plate or substrate without any other materials than quartz. Opacity is defined as the fraction of incident radiation (at actinic wavelength) that is absorbed while passing through a mask, more specifically, a mask plate or combination of materials in or on the mask plate. In the context of this invention a material is considered to be opaque (having a value of opacity nearing a value of 1) if practically all the light is absorbed in the material, e.g. darkly pigmented glass.

SUMMARY

Embodiments of the present invention utilize techniques that will allow the formation of a reticle by creating structures in a virgin reticle mask plate, the formation of which structures presents an opportunity to create multiple features that are not presently available in mask processing today.

Embodiments of the invention leave the top surface of a reticle which is completely planar, improving the imaging performance by reducing the scattering of light between features. Such a fully planar surface also allows the sealing of the top surface of the reticle without adverse effects, eliminating growth of defects on the features of the reticle.

One embodiment of this invention allows the difficult process of absorber etching to be replaced by a silicon dioxide etch into the quartz of a COG plate to form an etched pattern, followed by the process of filling the etched pattern with an actinic absorber.

As employed herein the term reticle is intended to be interpreted to be synonym of the terms mask, photomask, and photoreticle.

In accordance with an embodiment of this invention, a damascene method for manufacturing optical projection masks comprises patterning a substrate for an optical projection mask having a first level of transmissivity with a feature recess; and filling the recess with a material having a different level of transmissivity.

In one example, the method involves forming a projection reticle in a transparent substrate having a top surface with a feature recess in the top surface of the transparent substrate; and forming a radiation transmissivity modifying material in the feature recess. The radiation transmissivity modifying material comprises a material selected from the group consisting of an opaque material and a partially transmissive material.

In one example, the method involves forming a projection reticle in a transparent substrate having a top surface with a feature recess in the top surface of the transparent substrate, and forming a radiation transmissivity modifying material in the feature recess. The radiation transmissivity modifying material comprises a material selected from the group consisting of an opaque material and a partially transmissive material. A plurality of films may be included in the feature recess with the deposited films having different degrees of transmissivity. Preferably, the radiation transmissivity modifying material is selected from the group comprising at least two deposited films including an opaque film and a transmissive film and an opaque film deposited with a partially transmissive material.

In one example, a liner is formed juxtaposed with the radiation transmissivity modifying material as a lens for focusing the exposure rays at the edge of the pattern to increase signal to noise levels so that scattering from the projected pattern is minimized. Preferably a sacrificial material is present in the recess. Next, a material for modifying radiation transmissivity is formed juxtaposed with the sacrificial material. Then the sacrificial material is removed from the recess.

In one example, the radiation transmissivity modifying material is deposited as a film upon the transparent substrate; and the radiation transmissivity modifying material is planarized with a polishing slurry consisting of fumed silica, a pH of from about 2.2 to about 2.6, and a 1:10 dilution in water on the order of one part of about 84% to about 88% parts phosphoric acid to 9 parts water, preferably deionized water.

In one example, a reticle carrier is provided for a polishing tool capable of accommodating a reticle comprising a rigid base plate; a retaining ring; a reticle pad adapted for supporting a reticle inserted onto the reticle carrier; and the base plate with the reticle pad having a plurality of aligned passageways therethrough for exhaustion of air from the space between the base plate and a reticle; whereby a vacuum is generated to retain a reticle in place under vacuum conditions and application of air under pressure can eject a reticle from the reticle carrier.

In one example, a metal base plate is provided having a plurality of passageways therethrough, preferably including a reticle pad installed on the metal base plate with matching aligned plurality of passageways therethrough. It is also preferred that a reticle holding ring is provided made of a low friction material that is attachable to the base plate.

In accordance with another embodiment of this invention, a projection reticle is formed in a transparent substrate having a top surface comprising a feature recess in the top surface of the transparent substrate; and a radiation transmissivity modifying material is formed in the feature recess.

In one example, the radiation transmissivity modifying material comprises a material selected from the group consisting of an opaque material, and a partially transmissive material. A plurality of deposited films may be included in the feature recess with the deposited films having different degrees of transmissivity.

In one example, the radiation transmissivity modifying material is selected from the group comprising at least two deposited films including an opaque film and a transmissive film, and an opaque film deposited with a partially transmissive material.

In one example, the radiation transmissivity modifying material comprises an opaque film juxtaposed with a phase error correction material selected from the group consisting of a solid or a gas. Preferably the recess has sidewalls and the radiation transmissivity modifying material is spaced away from the sidewalls by the phase error correction material.

In one example, a liner is juxtaposed with the radiation transmissivity modifying material as a lens for focusing the exposure rays at the edge of the pattern to increase signal to noise levels, whereby scattering from the projected pattern is minimized.

In accordance with another embodiment of the invention, a slurry for reticle polishing comprises fumed silica with a pH of from about 2.2 to about 2.6; and with on the order of a dilution of one part of 84-88% phosphoric acid in about 9 parts of water, preferably deionized water.

Embodiments of the invention avoid the difficult absorber etch employed in the subtractive process employed in patterning COG masks.

Embodiments of the invention provide a method for fabricating an optical projection mask using DUV resists.

Still other embodiments of the invention maximize the choices of absorbing materials for the optical projection mask manufacturer; to increase throughput on pattern generating tools in the mask making environment (higher sensitivity of DUV resists); minimize scattering from the projected pattern by adding a liner to function as a lens; focus the exposure rays at the edge of the pattern to increase signal to noise levels; and use of different absorbing materials, therefore allowing to tune linewidth per exposure.

Embodiments of the invention provide a reticle carrier to hold the reticle during polishing with the carrier consisting of a metal base plate that has a number of passages through it; and to provide a reticle holding ring that is made of a low friction material that attaches to the base plate.

Embodiments of the invention will be more readily apparent from the following detailed description and appended claims when taken with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1A-1G** are schematic, elevational sections of a reticle mask plate during the process of manufacture of a damascene reticle in accordance with this invention.

FIG. **2A** shows a flow chart which describes the steps in accordance with the process flow illustrated by the drawings from FIG. **1A** to FIG. **1G**; and FIG. **2B** shows a flow chart which describes alternative steps in accordance with the process flow illustrated by the drawings from FIG. **1**A to FIG. **1**G.

FIGS. **3**A-**3**F are schematic, elevational sections of a reticle mask plate during the process of manufacture of another form of damascene reticle in accordance with the method of this invention in accordance with the method of this invention.

FIG. **4** is a flow chart which describes the steps in accordance with the process flow illustrated by the drawings from FIG. **3**A to FIG. **3**F.

FIG. **5** is a perspective view depicting a reticle in accordance with this invention in which an annular, via type via feature is formed for a structure, e.g. a semiconductor via, in a transparent reticle mask plate.

FIG. **6** shows a perspective view depicting a reticle in accordance with this invention in which an rectangular type line patterning feature is shown in a transparent reticle mask plate with the light passing material and the light blocking material formed in a linear feature recess leaving a narrow feature recess inside the light blocking film.

FIGS. **7**A-**7**F illustrate an alternative process of manufacture which provides a patterned damascene reticle in accordance with the method of this invention.

FIG. **8** is a flow chart which describes the steps of the process flow illustrated by the drawings from FIG. **7**A to FIG. **7**F.

FIGS. **9**A-**9**I illustrate the steps of a method of manufacture of a reticle mask plate which is patterned with feature recesses in accordance with this invention.

In combination, FIG. **10**A and FIG. **10**B show a flow chart of the steps of the process flow illustrated by the drawings from FIG. **9**A to FIG. **9**I.

FIG. **11** is a perspective view depicting a reticle with an open peripheral space via feature in accordance with this invention in which an annular, via type via feature is formed for a structure, e.g. a semiconductor via, in a transparent reticle mask plate.

FIG. **12** is a perspective view of an open peripheral space line feature in accordance with this invention depicting a reticle showing a rectangular type line patterning feature in a transparent reticle mask plate with the planarized light blocking material formed in a linear feature recess leaving a narrow feature recess inside the light blocking film

FIGS. **13**A and **13**B show sectional and bottom views respectively of a reticle polishing carrier in accordance with this invention which is adapted for use with a wafer polishing tool for the purpose of reticle polishing.

FIGS. **14**A and **14**B show sectional and bottom views respectively of the reticle polishing carrier of FIGS. **13**A and **13**B with a reticle inserted therein for polishing.

FIG. **15** is a table showing representative slurry formulation.

FIG. **16** is a table showing the processing parameters and equipment employed for performing an exemplary Damascene Reticle CMP (DRCMP) process in accordance with this invention.

FIG. **17** is a table showing an implementation of the DRCMP process of this invention.

FIG. **18** is a table showing transparent materials and their refractive indicies.

DETAILED DESCRIPTION

A common feature of various embodiments is the use of the Damascene Reticle CMP (DRCMP) in the formation of a damascene reticle. Another feature common to different embodiments is the formation of recessed trenches in a transparent plate.

Damascene Quartz Binary Reticle

In this embodiment, a damascene reticle in accordance with the invention is formed employing photolithography. Structures are formed in and/or upon a reticle starting with a blank, planar, transparent reticle mask plate adapted for creating features for use in processes in the manufacture of microelectronic devices.

First Embodiment of a Damascene Mask Plate Formed in a Transparent Reticle Mask Plate

Heretofore, mask plate reticles have been formed by patterning opaque material on the top surface of a transparent substrate. In accordance with this invention a damascene mask plate is formed by first forming a pattern of recesses in a blank, transparent, reticle mask plate. Then the recesses are filled with opaque and/or partially transmissive materials depending upon which type of damascene mask plate is being formed in accordance with this invention. Several embodiments thereof are described below with reference to the appended drawings. The substrate can be selected to be transparent for an exposure radiation of an appropriate wavelength to be used with such mask plate reticles. FIGS. **1**A-**1**F are schematic, elevational sections of a reticle **10** formed from a blank transparent reticle mask plate **11** (hereinafter mask plate **11**). The process of manufacture provides a patterned damascene reticle **10** shown in FIG. **1**G formed in accordance with the method of this invention. FIG. **2** is a flow chart which describes the steps of the process flow illustrated by FIGS. **1**A to **1**G. FIG. **1**G shows a complete, patterned damascene reticle **10** in accordance with this invention after completion of the manufacture thereof. The damascene reticle **10** (mask) of FIG. **1**G is adapted to be employed to expose patterns formed thereon.

FIG. **1**A shows the blank reticle **10** in the form of a blank, planar, transparent, reticle mask plate **11**, hereinafter mask plate **11**, (composed of quartz or silicon dioxide) in the initial stage of processing of step A in FIGS. **2**A and **2**B with a photoresist mask PR formed thereon. The mask plate **11** has a top surface upon which a blanket layer of photoresist PR is deposited and patterned into a mask PR. The mask PR is formed in accordance with photolithographic techniques, well understood by those skilled in the art. There is an open window W reaching down through the mask PR exposing the top surface of the reticle mask plate **11**, as will also be well understood by those skilled in the art. The mask plate **11** may comprise a virgin, planar quartz plate with no layer of chrome formed thereon. The top surface of the mask plate **11** is substantially flat or planar. Preferably, the photoresist mask PR may comprise a standard state-of-the-art DUV resist.

FIG. **1**B shows the previously blank reticle **10** of FIG. **1**A after initial patterning by etching through the window W down into the blank mask plate **11** to form an initial feature recess **12** in the form of a trench formed in the mask plate **11** according to step B in FIGS. **2**A/**2**B. The initial feature recess **12** extends down partially through the mask plate **11** from the top surface of reticle mask **10**. The initial feature recess **12** can be formed in a quartz or silicon dioxide mask plate **11** by using a conventional etching process, using either a wet etching or a dry etching process. For quartz or glass (silicon oxide) a wet etch can be performed with an acidic etchant, e.g. an aqueous hydrofluoric acid (HF) solution. A dry etch can be performed by Reactive Ion Etching (RIE) with a dry etchant such as CF_4. TetraMethylAmmonium Hydroxide (TMAH) which is a base can etch the initial feature recess **12** into a silicon mask plate **11**. TMAH is a quaternary ammonium salt with the molecular formula $(CH_3)_4NOH$ used as an anisotropic etchant of silicon; and TMAH can be used as a basic solvent in the development of an acidic photoresist in photolithographic processing of a workpiece.

FIG. **1**C shows the reticle **10** of FIG. **1**B after the photoresist mask PR is removed from the top of the patterned, mask plate **11** in accordance with step C in FIG. **2**.

FIG. **1**D shows the reticle **10** of FIG. **1**C after deposition of a radiation transmissivity modifying material on the top surface of the etched mask plate **11**. In this case the radiation transmissivity modifying material comprises a conformal, opaque-absorber film **15**C composed of an opaque material with a relatively uniform thickness. The absorber film **15**C is deposited on the top surface of the mask plate **11** and the sidewall and bottom surfaces of the initial feature recess **12** in accordance with step D in FIG. **2**. The conformal, opaque-absorber film **15**C leaves a recess **15**R defining a shallower and narrower feature recess **12'** (representing a latent feature **15**F.) The absorber film **15**C preferably comprises an opaque material selected to have optical characteristics adapted to block the radiation (e.g. light) which can be employed for exposure (onto workpieces being manufactured) of patterns of damascene features to be formed in the mask plate **11**. One such damascene feature **15**F is shown after completion of processing thereof as shown by FIG. **1**G.

FIG. **1**D shows how a mask plate **11** is being prepared to be patterned with the feature **15**F of FIG. **1**E. After step D is completed the initial feature recess **12** is narrowed (forming a potential, damascene feature **15**R) by the thickness of the conformal, absorber film **15**C which lines the sidewall surfaces as well as the bottom surface of the initial feature recess **12** of FIG. **1**B. In other words a narrowed feature recess **12'** remains inside the initial feature recess **12**. It is preferred to employ Chemical Vapor Deposition (CVD) to deposit the absorber film **15**C when it comprises TaN, Ta, Ti, TiN, Ni, W, SiO_2, SiN, or SiC or a combination thereof. Other deposition techniques can also be employed to deposit film **15**C, e.g. plating, atomic layer deposition, sputtering, evaporation, etc. that are all well known in the industry.

FIG. **1**E shows reticle **10** of FIG. **1**D after planarization by a process such as DRCMP in step E of FIGS. **2**A/**2**B to remove the uppermost (outer), exposed portions of the conformal layer of opaque material **15**C from the top surface of the mask plate **11**. The inner, remainder of the conformal layer of opaque material **15**P is formed into a patterned, opaque, damascene feature **15**F which remains on the sidewall surfaces and the bottom surface of the initial feature recess **12** of FIG. **1**E leaving a shallower feature recess **12"**.

FIG. **1**F shows the reticle **10** of FIG. **1**E after a deposition in accordance with step F in FIG. **2**A of a blanket transparent coating **16**B that will allow mask exposure, radiation, i.e. light, to pass through it and through the mask plate **11** as well, aside from the patterned, opaque, damascene feature **15**F. The transparent coating **16**B covers the top surface of the mask plate **11** and fills the shallower feature recess **12"** leaving the surface of the transparent coating **16**B with a depression **16**D therein above the shallower feature recess **12"** of FIG. **1**E. It is preferred to deposit the transparent coating **16**B by a CVD process. Alternatively, one can sputter and spin-on materials which are used as insulators (i.e. SiLK from Dow Chemical and flowable oxides) which can be deposited to form the transparent coating **16**B. These spin-on materials are applied in the same manner as photoresist. Additionally, if a spin-on component, is used, it can be planarized. The planarizing characteristics are dependant upon the viscosity of the material, as is well known by those skilled in the art.

FIG. **1**G shows the completed reticle **10** of FIG. **1**F after a step of planarization, e.g. DRCMP planarization in accordance with step G in FIG. **2**A. The DRCMP planarization of step G has transformed the blanket layer of transparent material **16**B of FIG. **1**F into a thin film **16**P of FIG. **1**G comprising a planar remainder of the transparent coating **16**B with a substantially planar top surface. The planar transparent coating **16**P continues to fill the shallower feature recess **12"** and covers the top surface of the reticle mask plate **11**, providing protection for the remainder of the conformal layer of opaque material **15**P (which forms the patterned, opaque, damascene feature **15**F) and the reticle mask plate **11**.

Alternatively in FIG. **2**B, steps F and G have been replaced by step F' in which spin coating a deposit of a blanket, planar, transparent layer **16**P (as shown in FIG. **1**G) covers both the mask plate **11** and the patterned, opaque, damascene feature **15**F formed from the absorber film **15**C.

In the processing in accordance with FIGS. **2**A and **2**B, it is preferable to deposit the layers by Chemical Vapor Deposition (CVD), where applicable.

Second Embodiment

Damascene PSM Reticle

FIGS. **3**A-**3**F are schematic elevational views of a damascene PSM reticle **30** during the process of manufacture of the reticle in accordance with another aspect of the method of this invention, as shown by the flow chart of FIG. **4**. FIGS. **3**A-**3**F illustrate process flow for patterning the reticle **30**. As shown in FIG. **3**F, the resulting reticle **30** has PSM features **36**F' which are composed of deposited conformal film elements **33**P/**35**P filling a feature recess **32** in a mask plate **31**. The reticle **30** is adapted to be used to expose patterns on a workpiece (not shown.) FIG. **3**F shows a patterned reticle **30** which is to be employed as a PSM mask after the manufacture thereof in accordance with this invention for exposing patterns formed thereon.

FIG. **3**A shows the reticle **30** in an initial stage of processing in accordance with step A in FIG. **4**. A transparent reticle mask plate **31** (hereinafter mask plate **31**) is shown with a top surface on which a photoresist mask PR is formed. As with FIG. **1**A, an open window W through photoresist mask PR reaches down to the top surface of the mask plate **31**, which may comprise a virgin, planar quartz plate with no layer of chrome formed thereon. The top surface of the mask plate **31** is flat or planar.

FIG. **3**B shows the reticle **30** of FIG. **3**A after an initial feature recess **32** was etched into the top surface of the mask plate **31** in accordance with step B in FIG. **4**. In step B, the reticle mask plate **31** is etched with a conventional etching process, as described above with reference to step B in FIG. **2**.

FIG. **3**C shows the reticle **30** of FIG. **3**B after removal of photoresist mask PR from the top surface of the mask plate **31** according to step C in FIG. **4**.

FIG. **3**D shows the reticle **30** of FIG. **3**B after deposition of a radiation transmissivity modifying material, which in accordance with step G in FIG. **4** comprises a conformal, partially-transmissive film **33**C (i.e. partially-transparent film). The partially-transmissive film **33**C is deposited on the top surface of the reticle **30** and the sidewalls and the bottom surface of the etched initial feature recess **32** leaving a narrower feature recess **32'** (forming a potential, damascene feature **33**R) representing a stage in the patterning of a feature **36**F' shown in FIG. **3**F. The conformal, partially-transmissive film 33C is selected to have optical characteristics adapted to provide partial blocking of the radiation (e.g. light) that can be employed for exposure (onto workpieces being manufactured) of patterns of features 36F formed on the reticle 10. In FIG. 3F the feature 36F' is shown after completion of processing of the device 30 by step I in FIG. 4 of CMP planarization to polish down both the actinic absorber film 35C and the partially-transmissive film 33C (i.e. partially-transparent film) to expose the top surface of the mask plate 31 forming an opaque patterned damascene feature 36F' defined by the portions of both films remaining in the recess in the mask plate reticle 10.

Summarizing, when step G in FIG. 4 is completed the initial feature recess 32 is narrowed into narrower feature recess 32' and reduced in depth by the thickness of the partially-transmissive film 33C which lines the sidewall surfaces and the bottom surface of the etched initial feature recess 32 of FIG. 3C forming the potential, damascene feature 33R. In other words a narrowed feature recess 32' remains inside the etched initial feature recess 32 which is lined with the partially-transmissive film 33C.

FIG. 3E shows the patterned reticle 30 of FIG. 3D after a conformal, actinic/light blocking, opaque-absorber film 35C is formed thereover in accordance with step H in FIG. 4. Thus, both laminated films 33C/33R including the partially-transmissive, conformal film 33C and the conformal, opaque-absorber film 35C cover the reticle 30. The opaque-absorber film 35C is deposited over the patterned reticle 30 with a relatively uniform thickness on the top surface of the partially-transmissive film 33C including the sidewall and bottom surfaces of the feature recess 32'. As a result, the opaque-absorber film 35C produces a potential feature 36F in the even narrower feature recess 32". The conformal, opaque-absorber film 35C preferably comprises an opaque material selected to have optical characteristics adapted to block the radiation (e.g. light) which can be employed for exposure (onto workpieces being manufactured) of patterns of damascene features to be formed in the mask plate 11. One such damascene feature 36F' is shown after completion of processing thereof as shown by FIG. 3F.

FIG. 3F shows the reticle 30 of FIG. 3E after the step I in FIG. 4 of planarization of the two laminated films 35C/33C down to the top surface of the mask plate 31. The initial feature recess 32 remains lined with the damascene PSM feature 36F composed of the combination of a remainder element 33P from partially-transmissive film 33C and a remainder element 35P from opaque-absorber film 35C (nested in remainder element 33P) which form the resulting damascene feature 36F'. In step I of FIG. 4 the conformal, opaque-absorber, actinic or light blocking film 35C, and the conformal partially-transmissive film 33C are polished away from the top of the reticle mask plate 31 by CMP planarization forming the damascene PSM Reticle 30. Thus, the resulting feature 36F' comprises the laminated combination of the remaining conformal partially-transmissive remainder film 33P which lines the sidewalls and bottom surface of the initial feature recess 32 and the remaining conformal, opaque-absorber film 35P which lines the conformal partially-transmissive remainder film 33P in the feature recess 32, leaving a shallower, narrowed feature recess 32" within the opaque-absorber remainder film 35P.

The blanket films 33C/35C may be composed of a material selected from Silicon Oxide (SiO_2), Silicon Nitride (Si_3N_4), and chromium (Cr) may be deposited on the reticle mask plate 31. These are known materials and offer options of not just passing light, but also changing the light. Those changes in the light can be employed to provide attenuation or phase shifting.

Third Embodiment

Damascene PSM Reticle In-Situ Lens Formation on the Reticle

In a modification of the embodiment of FIG. 3F, aside from the detail that the shape and index of refraction of the outer, partially-transmissive, remainder element 33P is tuned so that parallel, focused light beams come out of the top side of the reticle 30 as illumination is to be projected from below for all images. Improvements can employ multiple different layers with varying refraction indexes to improve the focus effect.

Fourth Embodiment

Via Feature

FIG. 5 is a top perspective view depicting a reticle 50 in accordance with this invention in which an annular, via type via feature 56F is formed for a structure, e.g. a semiconductor via, in a mask plate 51. The reticle 50 is made in accordance with the method of this invention, as shown by the FIG. 4 flow chart. In this case, as in FIGS. 3B and 3C and steps B and C in FIG. 4, a cylindrical initial feature recess 52 is formed in the reticle mask plate 51 by etching down into the mask plate 51. Then the initial feature recess 52 is lined with a conformal light passing film 33P (deposited as in FIG. 3D, according to step G in FIG. 4) which forms a narrower cylindrical recess 52'. Next the additional narrower cylindrical recess 52' is lined with a conformal light blocking film 35P (deposited as in FIG. 3E, according to step H in FIG. 4) covering the sidewalls and bottom thereof. Then a planarization step I in FIG. 4 is performed producing a via patterning feature 56F. A hollow well 52W remains inside the conformal light blocking film 35P.

Fifth Embodiment

Line Feature

FIG. 6 shows a top perspective view depicting a reticle 60 in accordance with this invention in which an rectangular type line patterning feature 66F is shown in a transparent reticle mask plate 61 (hereinafter mask plate 61) with the light passing material 33P and the light blocking 35P material formed in a linear feature recess 62 leaving a narrow feature recess 62W inside the light blocking film 35P. The reticle 60 is made in accordance with the method of this invention, as shown by the flow chart of FIG. 4. In this case, as in FIGS. 3B and 3C, the rectangular initial feature recess 62 is etched into the mask plate 61. Then the rectangular initial feature recess 62 is lined with a conformal light passing film 33P (deposited as in FIG. 3D, according to step G in FIG. 4) forming a narrower rectangular recess. Next the additional narrower rectangular recess is lined with a conformal light blocking film 35P (deposited as in FIG. 3E according to step H in FIG. 4) covering the sidewalls and bottom of the additional narrower rectangular recess. Then the planarization step I in FIG. 4 produces line patterning feature 66F. Thus the hollow well 62W remains inside the conformal light blocking film 35P. In summary, the line patterning feature 66F was formed in the rectangular initial feature recess 62.

Sixth Embodiment

Light Blocking Material Embedded in a Reticle

FIGS. **7**A-**7**F are schematic elevational views of the steps of forming a reticle **70** from a blank, transparent, reticle mask plate **71** (hereinafter mask plate **71**) illustrating an alternative method of manufacture of a patterned damascene reticle **70** in accordance with the method of this invention. FIG. **7**F shows a complete, patterned damascene reticle **70** in accordance with this invention after completion of the manufacture thereof. In FIG. **7**F a fully opaque feature **75**F is embedded in a feature recess **72** in the mask plate **71** of the reticle **70**. FIG. **8** is a flow chart which describes the steps of the process flow illustrated by the drawings from FIG. **7**A to FIG. **7**F. The damascene reticle **70** (mask) of FIG. **7**F is adapted to be employed to expose patterns formed thereon.

In FIG. **7**A, the process begins with a blank, planar, transparent reticle mask plate **71** in an initial stage of processing in accordance with step A in FIG. **8** with a photoresist mask PR formed thereon. The mask plate **71** (composed of quartz or silicon dioxide) has a top surface upon which a blanket layer of photoresist PR is deposited and then patterned into a photoresist mask. The mask PR is formed in accordance with photolithographic techniques which are well understood by those skilled in the art. There is an open window W reaching down through the photoresist mask PR exposing the top surface of the mask plate **71**, as will also be well understood by those skilled in the art. The transparent reticle mask plate **71** may comprise a virgin, planar quartz plate with no layer of chrome formed thereon. The top surface of the mask plate **71** is substantially flat or planar. Preferably, the photoresist mask PR comprises a standard DUV resist.

FIG. **7**B shows the previously blank reticle **70** of FIG. **7**A after initial patterning by etching through the window W down into the blank mask plate **71** to form a feature recess **72** in the form of a trench formed in the mask plate **71** extending down from the top surface of the mask plate **71** in accordance with step B in FIG. **8**. In step B, the feature recess **72** can be formed in a quartz or silicon dioxide, mask plate **71** by etching the feature recess employing a conventional etching process; or by using either a wet etching or a dry etching process as described above.

FIG. **7**C shows the reticle **70** of FIG. **7**B in accordance with step C in FIG. **8**, after the photoresist mask PR is removed from the top surface of the mask plate **71** in accordance with step C in FIG. **8**.

FIG. **7**D shows the reticle **70** of FIG. **7**C after deposition of a blanket, opaque-absorber film **75**B composed of an opaque material with a relatively uniform thickness on the top surface of the mask plate **71**, which fills the feature recess **72** in accordance with step J in FIG. **8**, leaving a depression **75**D over the feature recess **72**. The opaque material of the absorber film **75**B, which preferably has optical characteristics adapted to block the radiation (e.g. light), can be employed for exposure (onto workpieces being manufactured) of patterns of damascene features to be formed in the mask plate **71**. One such damascene feature **75**F is shown after completion of processing thereof as shown by FIG. **7**G. The layer **75**B is opaque to the actinic wavelength and completely fills up the feature recess **72**, which is a patterned trench.

FIG. **7**E shows the reticle **70** of FIG. **7**D after a planarization step such as DRCMP to remove the outer, exposed portions of the blanket opaque absorber film **75**B from the top surface of the mask plate **71** in accordance with step K in FIG. **8**. The inner, remainder **75**P of the blanket, opaque absorber film **75**B is formed into a patterned, opaque, damascene feature **75**F remaining in the feature recess **72** of FIG. **7**E.

FIG. **7**F shows the completed reticle **70** of FIG. **7**E after deposition in accordance with step L in FIG. **8** of a blanket, transparent coating film **77** covering the remainder **75**P of the film **75**B (i.e. the patterned, opaque, damascene feature **75**F) and the top surface of the mask plate **71**. The transparent coating film **77** allows mask exposure, radiation, i.e. light, to pass through it through the mask plate **71** as well, aside from the patterned, opaque, damascene feature **75**F. The transparent coating **77** provides protection from use or handling by encapsulating the remainder of the opaque absorber film **75**P (which forms the patterned, opaque, damascene feature **75**F) and the mask plate **71**.

Eighth Embodiment

Encapsulated Materials and Variable Index of Refraction

FIGS. **9**A-**9**L illustrate the steps of a method of manufacture of a reticle mask **100** patterned with feature recesses in accordance with this invention. FIGS. **10**A/**10**B show a flow chart of the processing steps shown by FIGS. **9**A to **9**L.

In the method of FIGS. **9**A-**9**L and the flow chart of FIGS. **10**A/**10**B, a reticle **100** is formed in a transparent reticle mask plate **101** (hereinafter mask plate **101**) shown in FIG. **9**A. Pattern the mask plate **101** with feature recesses **102** with sidewall surfaces **102**S and bottom surfaces **102**B (FIGS. **9**B/**9**C). Then deposit a conformal sacrificial film **103**C covering exposed surfaces on the top of the patterned mask plate **101** including the exposed surfaces **102**S/**102**B forming narrowed feature recesses **102'** (FIG. **9**D.) Next etch back the conformal sacrificial film **103**C is using an anisotropic inside spacer process that leaves recessed sacrificial film sidewalls **103**S on the sidewalls **102**S, while exposing the bottom surfaces **102**B forming deepened narrowed feature recesses **102"** (FIG. **9**E.)

Then deposit a conformal opaque film **105**C (FIG. **9**F), covering exposed surfaces including the bottom surfaces **102**B forming a pair of preliminary features **105**R with narrower and shallower feature recesses **102"**. Then in a DRCMP step, remove the external portion of the conformal opaque film **105**C from the top surface of the reticle **100** (FIG. **9**G) forming modified features **105**F with shallower recesses **102**F. Next, remove the recessed portions of the sacrificial film **103**S leaving gaps **107**O between the sidewalls **102**S and the features **105**F (FIG. **9**H). The gaps **107**O can be filled, preferably with a gas or generation of a vacuum employing conventional equipment as will be well understood by those skilled in the art. If a gas is used it is preferable to fill the gap **107**O with an inert gas to prevent unwanted reactions with the solid materials. Finally deposit a protective capping layer **109** over the features **105**F. At this point a planarizing step can be performed (not shown) if needed.

FIG. **9**A shows the reticle **100** in an initial stage of processing according to step A in FIG. **10**A. A blank mask plate **101** is shown with a photoresist mask PR formed thereover. As with FIG. **1**A, there are two open windows W through photoresist mask PR down to the top surface of the mask plate **101**. The mask plate **101** may comprise a transparent, virgin, planar quartz plate with no layer of chrome formed thereon. The top surface of the mask plate **101** is flat or planar.

FIG. **9**B shows the reticle **100** of FIG. **9**A after a pair of initial feature recesses **102** having sidewalls **102**S and bottom surfaces **102**B were etched into the top surface of the mask plate **101** in accordance with step B in FIG. **10**A. In step B, the reticle mask plate **101** is etched with a conventional etching process as described above in step B of FIG. **2**, exposing the bottom surfaces **102**B of the recesses **102**.

FIG. **9**C shows reticle **100** of FIG. **9**B after stripping the photoresist mask PR from the top surface of the mask plate **101** according to step C in FIG. **10**A.

FIG. **9**D shows reticle **100** of FIG. **9**C after deposition according to step M in FIG. **10**A of a conformal, sacrificial film **103**C on top of the reticle **100** and the sidewalls and the bottom surface of the etched initial feature recess **102** leaving a narrower feature recess **102'** representing a initial portion of a feature (feature **105**F in FIGS. **9**F-**9**I).

FIG. **9**E shows the reticle **100** of FIG. **9**D after performing an anisotropic inside spacer etching process in accordance with step N in FIG. **10**A removing the horizontally extending regions of the sacrificial film **103**C exposing the top surface of the mask plate **101** and the bottom surfaces **102**B leaving a pair of narrowed and deeper features **102"** and leaving the sacrificial film sidewall spacers **103**S on the sidewalls **102**S.

FIG. **9**F shows the patterned reticle **100** of FIG. **9**E after forming a conformal, actinic/light blocking, opaque-absorber film **105**C thereover in accordance with step P in FIG. **10**B. The conformal, opaque-absorber film **105**C covers the top surfaces of the reticle mask plate **101**, the bottom surfaces **102**B of both feature recesses **102"** and the exposed surfaces of the sacrificial film sidewall spacers **103**S. At this point, the opaque-absorber film **105**C and sidewall spacers **103**S have been deposited within the recesses **102**. The opaque-absorber film **105**C is deposited over the patterned reticle **100** with a relatively uniform thickness. As a result, the opaque-absorber film **105**C produces an even narrower feature recesses **102'''** defining preliminary features **105**R. The conformal, opaque-absorber film **105**C preferably comprises an opaque material selected to have optical characteristics adapted to block the radiation (e.g. light) which can be employed for exposure (onto workpieces being manufactured) of patterns of damascene features to be formed in the mask plate **101**. Two such damascene features **105**F are shown after completion of processing thereof as shown by FIGS. **9**H and **9**I.

FIG. **9**G shows the reticle **100** of FIG. **9**F after planarization of the opaque-absorber film **105**C in accordance with step Q in FIG. **10**B. The planarization step polishes away the conformal, opaque-absorber, actinic or light blocking film **105**C from the top surface of the mask plate **101** forming a pair of features **105**F from the planarized portion of the opaque-absorber film **105**C, inside the sacrificial sidewall spacers **103**S. The sacrificial sidewall spacers **103**S remain lining the initial feature recess **102** with light blocking features **105**F nested therein. However, at this point the now unwanted sacrificial sidewall spacers **103**S also remain in the feature recess **102**, and the narrower feature recesses **102'''** remain slightly shallower defining modified preliminary features **105**F.

FIG. **9**H shows the reticle **100** of FIG. **9**G after stripping the sacrificial sidewall spacers **103**S from the recess sidewalls **102**S (in accordance with step R in FIG. **10**B) leaving open spaces **107**O between the planarized conformal, opaque-absorber, actinic or light blocking features **105**F and the sidewalls **102**S. The narrower and shallower feature recesses **102"** remain with open spaces **107**O juxtaposed therewith. Sacrificial films, which are well known in the industry, can be carbonaceous materials that can be removed by oxygen based processes such as oxygen plasma stripping or other means.

Using this embodiment will allow filling of open spaces **107**O and then capping the reticle **100** as shown in FIG. **9**I wherein the open spaces **107**O have been filled with a transparent, phase-error-correction filler **107**F (in accordance with step S in FIG. **10**R) which can be solid or fluid (liquid or gas) to allow the exposure ambient to correct for any phase errors. This can be done for both via structures as well as line/space patterns. The index of refraction of the material in the open spaces **107**O/**107**F will determine the exact phase change in conjunction with the depth of the trench **102**. This embodiment allows precise control of the phase change of the actinic wavelength in the path through the space area by virtue of keeping the n*length constant, independent of processing variables.

FIG. **9**I shows reticle **100** of FIG. **9**H after formation of protective capping layer **109** (in accordance with step T in FIG. **10**B) over the surface of device **100** leaving the open spaces **107**O juxtaposed with the planarized conformal, opaque-absorber, actinic or light blocking film **105**P. The capping layer **109** can be laminated, sputtered, or applied by any other method that does not interfere with the gap. Alternatively, the protective capping layer **109** can be deposited without filling the gap **107**O. This is done by utilizing the dimensions of the gap. It is well known in the industry that deposition non-conformally by means of vapor deposition results in what is referred to as "poor gap fill" in the industry. It is this very same "poor gap fill" that is employed at this stage in the process to create an embedded/protected unfilled gap in accordance with this invention. At this point planarization (not shown) can be performed.

Ninth Embodiment

Open Peripheral Space Via Feature

FIG. **11** is a top perspective view depicting a reticle **110** in accordance with this invention in which an annular, via type via feature **116**F is formed for a structure, e.g. a semiconductor via, in a mask plate **111** comprising a transparent reticle mask plate. The reticle **110** is made in accordance with the method of this invention, as shown by the flow chart in FIGS. **10**A/**10**B. As in FIGS. **9**B and **9**C and steps B and C in FIGS. **10**A/**10**B, first step is to etch the cylindrical initial feature recess **112** down into the mask plate **111**. Then line the cylindrical initial feature recess **112** with a sacrificial layer (not shown) as described above (FIGS. **9**E and **9**F, steps M/N in FIG. **10**A) and form a narrower cylindrical recess **112'**. Next, line the narrower cylindrical recess **112'** with an actinic absorber film as in FIGS. **9**E and **9**F (according to steps P and Q in FIG. **10**B) and planarize to form the actinic absorber film **115**P thereby producing a via patterning feature **116**F. Then remove the sacrificial layer as in FIG. **9**H and step R in FIG. **10**B. A hollow well **112**W remains inside the conformal light blocking film **115**P and there is an open, i.e. hollow, annular space **117**O separating the planarized conformal, opaque-absorber, actinic or light blocking film **115**P from the sidewalls of the original recess **112**.

Tenth Embodiment

Open Peripheral Space Line Feature

FIG. **12** shows a top perspective view depicting a reticle **120** in accordance with this invention in which an rectangular type line patterning feature **126**F is shown in a mask plate **121** (comprising a transparent reticle mask plate) with the planarized light blocking **125**P material formed in a linear feature recess **122** leaving a narrow feature recess **122**W inside the light blocking film **125**P. The reticle **120** is made in accordance with the method of this invention, as shown by the flow chart of FIGS. **10**A/**10**B. In this case the first step is to etch a rectangular initial feature recess **122** into the mask plate **121**. Then line the rectangular initial feature recess **122** with a sacrificial film (not shown) forming a narrower, rectangular recess **122'**. Then planarize the sacrificial film to form a sacrificial sidewall spacer, as described above with respect to FIGS. **9**D-**9**E. Next line the additional narrower rectangular recess **122'** with a conformal light blocking film covering the sidewalls and bottom of the additional narrower rectangular recess. Then planarize to produce a line patterning feature **126**F. A hollow well **122**W remains inside the conformal light blocking film **125**P. Then remove the sacrificial material leaving a peripheral open space **127**O surrounding the light blocking film **125**P. In summary, the line patterning feature **126**F was formed in the rectangular initial feature recess **122**.

Damascene Reticle Chemical Mechanical Planarization

The processing required to achieve the above embodiments requires a method of Damascene Reticle Chemical Mechanical Planarization (DRCMP) of damascene reticles which is different from Semiconductor Wafer CMP (SWCMP) of semiconductor wafers. The DRCMP method is different from SWCMP because a reticle mask has a very different size and shape compared to a silicon wafer. Also, the necessary films on a reticle mask can be deposited in a different order from the order employed for performing SWCMP on surfaces of a silicon wafer. The following example is provided to facilitate explanation of the process involved, while it is intended to be clear that the materials can be changed and/or the order changed as will be well understood by those skilled in the art.

After a feature is etched into a reticle mask plate a conformal layer of optically transparent or light wave passing material is deposited. The material can be selected from a range of materials that include but are not limited to silicon dioxide (SiO_2), silicon nitride (Si_3N_4), and TEOS. Experimentation was done with silicon nitride. A problem with the structure of this invention is that a silicon nitride layer formed on a silicon dioxide substrate is formed in the reverse order from that usually employed by SWCMP planarization. A silicon nitride layer is usually used as a polish stop especially when polishing silicon oxide, as is well known in the industry. A number of silica based slurries appropriate for such CMP processing are commercially available for the conventional SWCMP application. The relative polish rates, or selectivity, of these slurries typically range from about 3:1 to about 4:1, with silicon dioxide having the higher polish rate.

In contrast in the case of embodiments of the present invention, for reticle polishing, it is necessary to polish the silicon nitride and then to stop on the top surface of the reticle which is composed of quartz that is a material which is very similar to silicon dioxide used in the semiconductor industry. This requires provision of a slurry and a process with the reverse selectivity to the silica based slurries described above whereby the silicon nitride polish rate is substantially higher than the silicon dioxide polish rate.

Slurry Formulation

A slurry formulation in accordance with this invention (described below) provides the needed "reverse selectivity," with a ratio of polish rates where the silicon nitride is polished at a rate 3 to 4 times faster than the silicon oxide. Thereafter Tantalum Nitride (TaN) and Tantalum (Ta) were deposited to allow this material to be the internally placed light blocking material. It was therefore necessary to employ semiconductor polishing chemistries and processing to provide adequate removal of the materials from the upper surface of the reticle mask plate without disrupting the internally placed materials (with reference to the plate) and avoiding damage to the upper surface that would result in unwanted imaging on the reticle mask plate the image is projected upon.

Two exemplary slurry chemistries, tool types, and process parameters are described next. There are many different process tools available and the process parameters will vary as the tool models vary as will be well understood by those skilled in the art.

1) Ta CMP Slurry and Process, Stopping on Silicon Nitride

A semiconductor slurry is employed to remove TaN/Ta (Tantalum Nitride/Tantalum) stopping on the silicon nitride. The slurry formulation suppresses a silicon oxide and silicon nitride polish rate while maintaining a Ta polishing rate. A representative slurry formulation is shown in FIG. **15**.

Damascene Reticle CMP Process

In FIG. **16**, a table is shown with the processing parameters and equipment employed for performing an exemplary DRCMP process in accordance with this invention.

2) CMP Slurry and Process for Removing Si_3Na and Stopping on SiO_2.

A slurry formulation is provided to remove silicon nitride and stop on silicon oxide. The selectivities are reversed as compared to a normal silica slurry. The slurry is prepared using a commercially available fumed silica suspension in water. This starting material, as obtained, is stabilized in alkaline media, with potassium hydroxide or ammonium hydroxide, to a pH of 9.5 to 12. The "reverse selectivity" slurry is prepared by adjusting the pH of the starting material to 2.4 (range 2.3 to 2.5) with dilute phosphoric acid. This acid solution is prepared by diluting 1 part of 86 percent phosphoric acid with 9 parts of water. The final pH of the slurry is critical to achieving the desired ratio of polish rates. The preparation of this slurry is shown in the table of FIG. **16**.

CMP Process

In FIG. **17** another table is shown with an implementation of the DRCMP process of this invention.

Reticle Polishing Carrier

FIGS. **13**A and **13**B show sectional and bottom views respectively of a reticle polishing carrier **200** in accordance with this invention which is adapted for use with a wafer polishing tool for the purpose of reticle polishing. FIGS. **14**A and **14**B show sectional and bottom views respectively of the reticle polishing carrier **200** of FIGS. **13**A and **13**B with a reticle **210** inserted therein for polishing.

Referring to FIGS. **13**A and **13**B and **14**A and **14**B, a reticle polishing carrier **200** in accordance with this invention is shown which is adapted for use with a wafer polishing tool (not shown) for the purpose of DRCMP reticle polishing. This is significant because such polishing tools are made for SWCMP polishing of semiconductor wafers, which are round and have a relatively small thickness on the order of only 0.03 inches (0.0762 cm) as compared to a damascene reticle that is square or rectangular that has a relatively large thickness of about 0.25 inches (0.635 cm) which is approximately an order of magnitude larger.

Accordingly it was required to fabricate a reticle polishing carrier **200** for a wafer polishing tool capable of accommodating a thick reticle **210** shown in FIG. **14**A. The reticle polishing carrier **200** is made of component parts that include a rigid base plate **201**, a retaining ring **205**, and a reticle pad **207** to support the reticle **210** when it is positioned in place, i.e. mounted, on the reticle carrier **200**. The inner edges **206** match the external dimensions of the reticles to be process to retain such reticles **210** (shown in FIGS. **14**A/**14**B in position during planarization. The retaining ring **205** is made of a chemically inert yet dimensionally stable polymeric material such as PolyTetraFluoroEthylene (PTFE), Delrin, PolyEtherEtherKetone (PEEK), and other similar commercially available materials.

The base plate **201** is preferably made of a rigid but corrosion resistant material such as titanium or stainless steel. The base plate **201** and the reticle pad have a series of matching aligned passageways **208** therethrough for exhaustion of air from the space between the base plate **201** and the reticle **210**. Additionally, a vacuum can be applied via passageways **208** to retain the reticle **210** in place while the reticle is being transported into position for polishing on the CMP pad and transported off the CMP pad after completion of polishing. During the actual polishing process air pressure can be applied to the back side of the reticle **210**. This has the advantage of distributing the downwardly applied force across the entire area of the reticle **210**, to improve the uniformity of material removal.

The thickness of a retaining ring **205** is selected to match the specified thickness of the reticle **210** so that the surface **210**S of the reticle **210** and the surface **205**S of the retaining ring **205** are nearly coplanar. This is essential to enable the uniform removal of material from the square reticle **210**, using a semiconductor manufacturing tool designed for SWCMP processing of round wafers. By making the surfaces of the reticle **210** and the retaining ring **205** nearly coplanar, the square shape of the reticle **210** will be properly embedded in the carrier **200**, and a problem will be avoided in that the straight edges of the reticle **210** will not be disproportionately eroded by the polishing pad (not shown.) The polishing process can be further optimized for uniformity across the diameter of the reticle **210** by careful adjustment of the level of the exposed reticle surface **210**S to be just above or just below (by plus or minus approx 0.010 inches) the surface **205**S of the retaining ring **205**. Raising the reticle **210** higher than the retaining ring **205** will increase polishing at the edge of the reticle **210**, while lowering the reticle surface **210**S will decrease polishing at the edge.

"Delrin is the brand name for an acetal resin engineering plastic invented and sold by DuPont. Often marketed and used as a metal substitute, Delrin is a lightweight, low-friction, and wear-resistant plastic capable of operating in temperatures in excess of 90° C." Other names for this compound include: PolyOxyMethylene (POM), acetal resin, polytrioxane and polyformaldehyde."

Materials Suitable for a Blank Transparent Mask Plate

A list of materials preferred for blank transparent mask plates includes crystalline aluminum oxide, lithium indium selenide, fused silica, ther materials which may be suitable for various optical ranges. It is necessary to match the material to the wavelength for either blocking or passing the energy. For example aluminum oxide (Al_2O_3), and beryllium can be used for x-ray. Calcium fluoride (CaF_2), zinc selenide (ZnSe), sodium chloride (NaCl), barium fluoride (BaF_2) can be used for infrared. Al_2O_3 which has several crystal forms which are called corundum, sapphire or ruby (depending on the color.) Sapphire comprises a single-crystal form of Al.sub.2O.sub.3 can be employed for infrared optical applications. Sapphire is unique when compared to optical materials useful within its transmission range because it is strong, and tough. Also, sapphire is resistant to both thermal shock and chemicals, and can be used at high temperatures. The thermal conductivity of sapphire is relatively high despite its extreme electrical non-conductivity. Sapphire has a moderate refractive index, transparency in the visible range of wavelengths, good transmission and relatively low emission at high temperatures plus unusual stability. CaF_2 can be used as a window material for both infrared and ultraviolet wavelengths At wavelengths as low as 157 nm, CaF_2 is useful for semiconductor manufacturing and as an ultraviolet optical material for integrated circuit lithography. CaF_2 is transparent in the range from about 0.15 μm to about 9 μm at which it exhibits extremely weak birefringence. BaF_2 is transparent from the ultraviolet to the infrared, from about 150-200 nm to about 11-11.5 μm, and can be used as a material to make optical components such as lenses. BaF_2 is used in windows for infrared spectroscopy and its transmittance at 200 nm is relatively low at 0.60, but at 500 nm it goes up to 0.96-0.97 and stays at that level until 9 μm, then falls off (e.g. 0.85 for 10 μm and 0.42 for 12 μm). Magnesium fluoride (MgF_2) is transparent over a wide range of wavelengths. Windows, lenses, and prisms made of MgF_2 can be used over the entire range of wavelengths from 0.140 μm (ultraviolet) to 8.0 μm (infrared). FIG. **18** shows a list of certain transparent materials and their refractive indicies.

ADVANTAGES OF THE INVENTION

The method of this invention increases the yield of optical projection mask making in terms of resolution and the process window. The method of this invention improves yield in the fabrication of integrated circuits due to smaller line edge roughness. The method of this invention also improves the lifetime of optical projection masks due to the fact that the patterns in the mask have damascene patterns embedded in a reticle mask plate.

The foregoing description discloses only exemplary embodiments of the invention. Modifications of the above disclosed apparatus and methods which fall within the scope of the invention will be readily apparent to those of ordinary skill in the art. While this invention is described in terms of the above specific exemplary embodiment(s), those skilled in the art will recognize that the invention can be practiced with modifications within the spirit and scope of the appended claims, i.e. changes can be made in form and detail, without departing from the spirit and scope of the invention. Accordingly, while the present invention is disclosed in connection with exemplary embodiments thereof, it should be understood that changes can be made to provide other embodiments which may fall within the spirit and scope of the invention and all such changes come within the purview of the present invention and the invention encompasses the subject matter defined by the following claims.

The invention claimed is:

1. A damascene reticle formed in a transparent substrate having a top surface comprising:

a feature recess formed in said top surface of said transparent substrate; and

a radiation transmissivity modifying material formed in said feature recess.

2. The damascene reticle of claim **1** wherein said radiation transmissivity modifying material comprises a material selected from the group consisting of an opaque material, and a partially transmissive material.

3. The damascene reticle of claim **1** wherein a plurality of deposited films are included in said feature recess with said deposited films having different degrees of transmissivity.

4. The damascene reticle of claim **1** wherein said radiation transmissivity modifying material is selected from the group comprising:

at least two deposited films including an opaque film and a transmissive film; and

an opaque film deposited with a partially transmissive material.

5. A damascene reticle formed in a transparent substrate having a top surface comprising:

a feature recess formed in said top surface of said transparent substrate; and a radiation transmissivity modifying material formed in said feature recess;

wherein said radiation transmissivity modifying material comprises an opaque film juxtaposed with a phase error correction material selected from the group consisting of a solid or a gas.

6. A damascene reticle formed in a transparent substrate having a top surface comprising:

a feature recess formed in said top surface of said transparent substrate; and

a radiation transmissivity modifying material formed in said feature recess;

wherein said feature recess having sidewalls, and said radiation transmissivity modifying material being spaced away from said sidewalls by a phase error correction material.

7. A damascene reticle formed in a transparent substrate having a top surface comprising:

a feature recess formed in said top surface of said transparent substrate;

a radiation transmissivity modifying material formed in said feature recess; and

a liner juxtaposed with said radiation transmissivity modifying material as a lens for focusing the exposure rays at the edge of the pattern to increase signal to noise levels, whereby scattering from the projected pattern is minimized.

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